Aalto University
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A Study on Future Multipurpose Vessels for the Northern Baltic Sea

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Master's thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering

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In spite of significant changes in cargo flow, the Northern Baltic Sea routes are still growing and continuing to play a key role to the Finnish economy because of its important trade connection. However, transporting versatile cargo demands efficient multipurpose vessels which should be cost effective for the industry and comply with all the future pollution control regulations of International Maritime Organization (IMO). Therefore, shipping industry needs to find solution and develop efficient vessel concept to survive in future competition.

This thesis studies the feasibility of Multipurpose vessels as future dry cargo transportation on the Northern Baltic Sea and future trends in designing Multipurpose vessel along with its market condition, fleet development and trade condition. Five alternative machinery concepts for multipurpose vessels are also analyzed to find the best environment friendly and cost-effective machinery solution for the future.

This study analyzes the current industry situation and identified future changes in cargo flow based on statistical data, market study, and other theses work. Future forecast is made for different cargo flow, supply and demand, multipurpose vessels fleet development and economy using SQL data mining forecasting techniques in Microsoft excel based on Time series of statistical data. Five alternative machinery concepts are analyzed using operational profiles of a case vessel, with a program called "ShipMac" developed by Wärtsilä Finland Oy.

This study founds out that most of the cargo will come from the Finnish Metal and mining industry while reduction in material flows from forest industry in the future. The renewable energy industry provides greater opportunity in the near future. Significance of Multipurpose vessels will increase if the amount of project cargo volume increases as fierce competition from containerships is the reality today. Containerization of break bulk might change the fate of multipurpose vessel. However, the long term prospects of multipurpose vessel have been found to be promising. Furthermore, machinery concept studies found out that single screw propulsion with 2-Stroke dual fuel Wärtsilä engine running on LNG as the main fuel is the most economical solution and comply with all the future environmental legislations. Therefore, standardization of multipurpose vessel design suitable for Baltic Sea and developing LNG infrastructure is the recommendation for future research.

Keywords: Multipurpose vessels, LNG, Finnish industry, Baltic sea, Dry Cargo, Propulsion

Preface

Being an international student, it was an enjoyable and challenging experience for me to work for Finnish Maritime Industry. This thesis is part of "LAIVA 2025" project and I would like to give a special thanks to my supervisor professor Pentti Kujala for providing the opportunity to work as a part of this project. I would also like to thank him for his thoughts and help throughout the work process.

Another special thanks to my instructor Ilkka Rytkölä from Wärtsilä Finland Oy for his guidance and help during my thesis work. I would also like to thank Tuomas Sipla from Wärtsilä Finland Oy for helping me doing the analysis with ShipMac program. At the same time, I am grateful to the people from other partner companies: Cargotec, ESL Shipping, Langh Ship, Outokumpu Stainless Oy, Stora Enso and University of Turku (Centre for Maritime Studies) for providing their valuable feedbacks and comments on several meetings.

I would finally like to thank my family for supporting and helping me during my study in Finland.

Espoo 23.08.2013

Golam Mortuja

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Abbreviations

CPP	Controllable Pitch Propeller
CRP	Contra-rotating Propeller
DAS	Double Acting Ship
DWT	Deadweight
ECA	Emission Control Area
EEDI	Energy Efficient Design Index
EWEA	European Wind Energy Association
GW	Gigawatt
IMO	International Maritime Organization
LNG	Liquefied Natural Gas
LDT	Light Displacement Tonnage
MPV	Multipurpose Vessel
NPV	Net Present Value
OECD	Organization for Economic Co-operation and Development
SECA	Sulphur Emission Control Area
ShipMac	Ship Machinery Comparison (Computer Program)
TEU	Twenty feet equivalent unit
TWh	Terawatt per hour
UNCTAD	United Nations Conference on Trade and Development

1 Introduction

Since about 90 percent of Finland's export and around 70 percent of import products are transported by sea, maritime transport is the key engine driving the economy of Finland [1]. It is important that Finnish maritime transport be developed systematically for the future, and that its competitiveness is ensured. Geographical position of Finland, along with challenging seasonal winter navigation conditions demand- competitive logistics solutions, swift maritime transportation and efficient cargo handling facilities. However, major Finnish industry segments have undergone tremendous changes in recent decades. In addition to that, new rules and regulations to minimize environmental pollutions in the Baltic Sea Region pose new challenges for the industry. Several actions are being implemented in order to save the marine ecosystems in the Northern Baltic Sea. The international Maritime Organization (IMO) controls pollution from ship through the "International Convention on the Prevention of Pollution from ships", known as MARPOL 73/78. The IMO NOx emission standards are commonly referred to as Tier I, II and III. These requirements are being gradually and will come into force in 2015 and 2021 [2]. Therefore, shipowners are facing challenging moments with a limited number of options for modifying their existing ships to comply with the new environmental legislations and continue to trade profitably in the Baltic Sea region. Newbuildings are also searching for best possible solution to survive in the long run. Therefore, it is necessary to develop strategies to meet future needs in terms of cargo transportation, environmental legislations and economic challenges.

Although a change in industry segments and material flow create many challenges, it also opens many new opportunities for the maritime industry. Due to the ongoing changes in the industrial structure of Finland, the situation in 2025 is likely to be far different than the present time. The recent report of the Centre for Maritime Studies- University of Turku, which is a part of "LAIVA 2025" project, developed different scenarios by considering future dry cargo transportation requirement for the Finnish foreign trade. One of the scenarios suggested that multipurpose vessel (MPV) will be the most suitable vessel type of the future for dry cargo transportation in the Baltic Sea region [3]. LAIVA 2025 is a project which aims at generating alternative and optimal vessel concepts for future dry cargo transportation in Finnish foreign trade by considering changes and factors affecting the operational environment. The project is funded by the Finnish Funding Agency for Technology and Innovations (TEKES) and the following six industrial companies: Cargotec, ESL Shipping, Langh Ship, Outokumpu, Stora Enso and Wärtsilä. This Project consists of three theses based on three different field of research.

This thesis has three objectives and one of the main objectives is to create future perceptions for the development of Finnish Maritime dry cargo transport in 2025 on the Baltic Sea. Identifying future challenges, opportunities and market situations for the multipurpose vessels (MPVs) are also an important goal of the research work. Another main purpose of this thesis is to analyze different alternative machinery concepts for future MPV to identify the most environments friendly and cost-effective machinery solution for the shipowners. This is accomplished by using the software named "ShipMac" developed by Wärtsilä, which used operational profile of an existing multipurpose vessel, M/S Aila. At the final stage of the thesis, visual concepts are developed for the future multipurpose vessel.

This thesis consists of eight chapters. Chapter two focuses on the world seaborne trade and future trends of the world's economy. In the chapter three, major Finnish maritime industry segments are evaluated based on other's thesis, the "Laiva 2025" report and further market study. This chapter also discussed about material flow in terms of both import and export cargo of Finland. SWOT (Strengths, Weakness, Opportunities and Threats) analysis for Finnish maritime industry. In the chapter four, future cargo flow on the Northern Baltic Sea is discussed and the need for multipurpose vessel in future dry cargo transportation is further justified h. Economic challenges and technical difficulties for the future multipurpose ship are also discussed in this chapter. Chapter five discussed the characteristics and design features of multipurpose vessels along with the future vessel size, speed trends and cargo handling facilities with the future technology concepts and the challenges due to new environmental regulations. Multipurpose shipping market is evaluated with respect to Finnish and global trade condition. This chapter also includes the forecast which is done for MPV shipping market by analyzing the MPV fleet development, freight market condition, and other competitive market segments. Future alternative machinery concepts for multipurpose vessel are discussed in chapter Six. Detail of the different cases and results from ShipMac software are included in this chapter. Chapter seven presents the example of MPV concept suitable for the Baltic Sea and different possible cargo carrying scenario while chapter eight summarizes the work by combining the outcome of each chapter and also identifies the scope of future research providing new challenges and recommendations.

2 World Seaborne Trade

Maritime transport is the backbone of the world economy and key engine driving globalization. It is usually accepted that more than 90% of the global trade, which is carried by sea, is dominated mainly by three economic centers, North America, Europe and Asia [4]. Europe is still world's biggest trading partner which is divided into mainly three areas, which are Western Europe, the Baltic Sea and the Mediterranean Sea [4]. As shipping is more global in nature and constantly changing, it is important to analyze world seaborne trade situation and trends to understand the changes that can affect the local shipping market in the future.

World seaborne trade is directly in relation with the rate of gross domestic product (GDP) and industrial production in the main economic region. Global economy is still recovering so as the world seaborne trade.

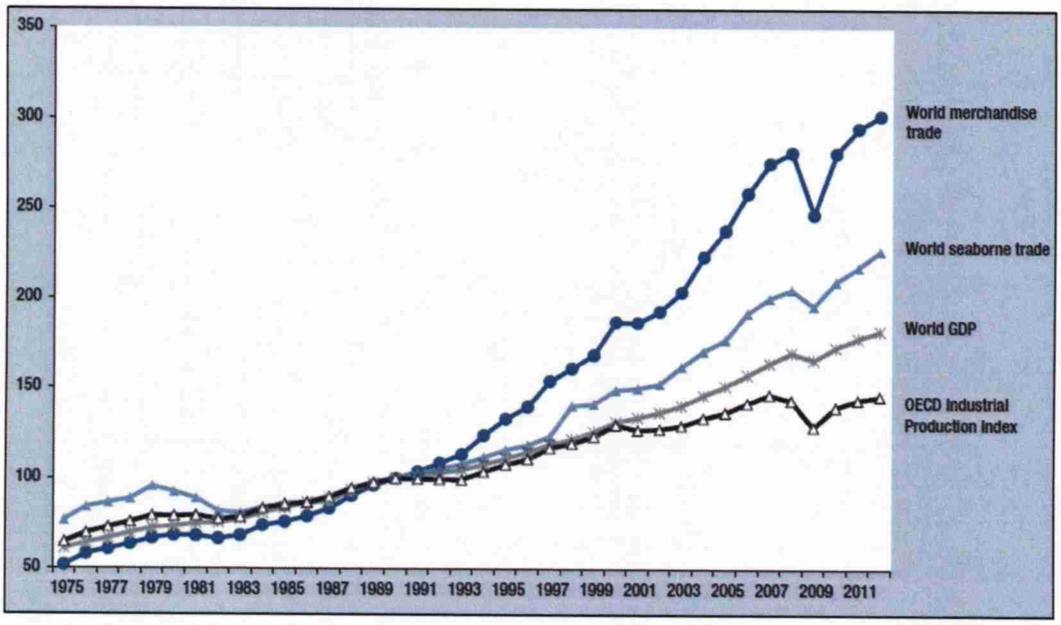


Figure 1 *The OECD Industrial Production Index and indices for world GDP, world merchandise trade and world seaborne trade (1975–2012) (1990 = 100) [Source: UNCTAD]*

Figure 1 shows that after the worse situation in 2009, world GPD have taken some time to pick up once again. It is found that world's GDP growth rate was about 3.2% in 2012, which was about 4% in 2011 [5]. GDP growth rate of Finland for Baseline scenario is assumed to be 1.7% from 2015 to 2030 [6]. Europe is still having sovereign debt crisis while the economy of United States of America is recovering slowly. Some other factors like global financial risks, social unrest in North Africa and Western Asia, natural disasters in Japan and Thailand which had disrupted regional and global supply chains, rising oil prices and volatility, austerity measures, and geopolitical tensions in the Strait of Hormuz had strong impact on world economy [7]. However, world seaborne trade held steady growth rate of 4% in 2011 reaching about 8.7 billion tonne fueled by the expansion of dry cargo, container and major bulk trades [7]. **Figure 2** shows the world seaborne trade for different trade segments in million tonnes per year and for the year of 2013, is forecasted by Clarkson research service.

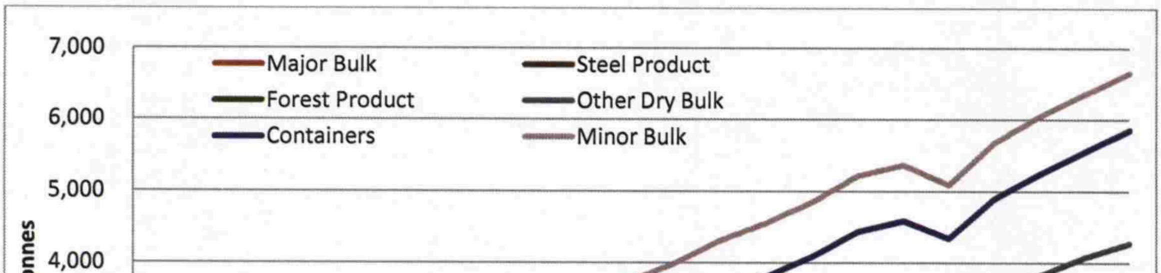


***Figure 2** World Seaborne Trade (million tonnes) (source of Data: Clarkson)*

Major bulk includes five major commodities consist of iron ore, coal, grain, bauxite/ alumina and phosphate rock which are accounted for 42 percent of the total dry cargo in the year of 2011 [7]. Overall dry bulk trade is forecasted to grow about 4.4 percent in 2013 which is dominated by imports to China and the Asian economy [7]. Steel consumption by China and other developing countries will continue to have major influence on the growth of the iron ore trade. Global crude steel production in 2011 was about 1,498 million tonnes which was 5% higher than 2010 [8]. Growth of Minor bulk which includes cements, ores, fertilizers, steel, was decelerated to 6.1 percent in 2011 [7]. Export of metal and minerals have recorded second fastest growth of about 7.4 percent after agribulk which had about 8.7 percent of growth rate in 2011 [7].The pattern of demand for forest products is shifting globally reducing the trade volume. Emerging economies such as Brazil, China and India is regarded as future demand generators for the global forest products industry. Containerization of various cargos like steel scrap, recycled paper, bulk commodities and other general cargo is contributing to increase the market share of container trade.

A very recent study by Lloyd's Register, QinetiQ and the Glasgow, Scotland-based University of Strathclyde named "Global Maritime Trends 2030" suggested that the Global seaborne trade is expected to be doubled by 2030 as a result of China's rapidly growing demand for commodity like crude oil, iron ore and other natural resources. The volume of world seaborne trade could reach between 19 and 24 billion tonnes a year by 2030 and the greatest growth in the container trade will take place between the Far East and the Middle East for the next two decades [9]. Developing countries will contribute significantly to the growth of World GDP, merchandise trade and seaborne trade as well. Total of 60% the volume of world seaborne trade originated in the developing countries in 2011 [7]. However, a scenario developed by MIT researcher predicted that around 2030 there will be a global collapse as a result of deteriorating world financial situation, climate change, rising energy prices, scarcity of water, food and other resources, internal unrest and mass starvation [9] (***Figure 3***). If it really happen as forecasted, the effect on shipping market will be avoidable.

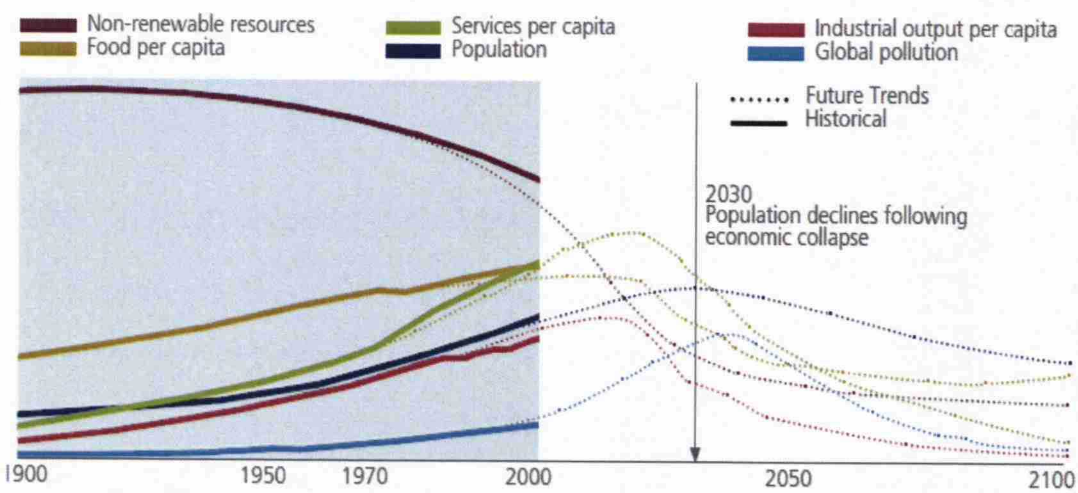


Figure 3 *Global Collapse*

(Source: Donella H. Meadows, Dennis L. Meadows, Jørgen Randers and William W. Behrens, III, "Limits to Growth", 1972 ,G. Turner "A Comparison of the Limits to Growth with Thirty Years of Reality", CSIRO Working Paper 2008-09)

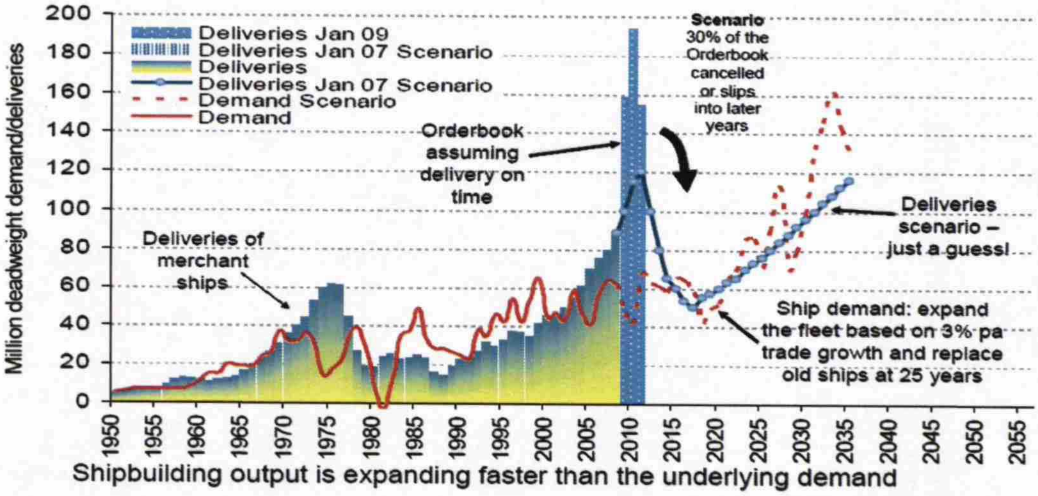


***Figure 4** Shipbuilding Investment demand and actual deliveries scenario [10]*

Clarkson Research has also established a similar scenario for shipping industry by comparing the demand for new ships with the supply from shipyards, shown in **Figure 4**. Here the red line indicates the demand for new ships based on growth of trade and the scrapping rate of old ships with an assumption that trade grows at around 3% per year and ships are scrapped at 25 years age [10]. Due to the new pollution control regulations in the Emission Control Area (ECA) many ships will be forced to scrap as a reason of higher modification cost to fulfill the environmental requirements. Therefore, between the year 2020 and 2030, it is expected to face an experience of volatile shipping market condition, even though the year of ship demand collapse and previous global collapse appear to be on slightly different time.

There are a number of challenges ahead in the future for the shipping industry as globalization is creating huge pressure on energy and raw material reserves as oil and steel related industries are likely to increase their import. At the same time, increasing the energy prices will continue to be a major issue for the industry. If the global energy consumption become lower and energy efficiency increases that could drive seaborne trade below the GDP trend [4]. In addition to that, more complex situation is being created by increased volatility in the shipping market because of overcapacity of the vessels. New environmental legislation and increasing fuel price demanding to look for alternative improved solution for the industry to minimize the cost and increase the efficiency of the future vessel. Therefore, to survive in the future global turmoil, an integration and collaboration with different organization and agencies is needed to develop suitable futuristic shipping business model.

3 Finnish Maritime Traffic and Future Scenario

Finland being an island like nation with long coastline and extensive inland waterways, always dependent on sea for the international competitiveness and economic success. Maritime transports are very much essential for Finland as over 80% of the foreign trade of the country is seaborne, therefore, shipping will continue to play major role in the future [3]. Energy production, health care, food production and all the other exporting industries are dependent on imported supplies transported by ships. Thus any failure in maritime transports can have very much disruptive consequences not only to the supply chains but also to the national security of supply and daily life of the people in Finland [11].

Baltic Sea route is one of the important connections from Finland to the mainland of EU. But due to worldwide economic crisis in 2008, the volume of transportation on the Baltic Sea via Finnish ports decreased by 19% in 2009 compared to the record year of 2007 [3]. From 2010, the volume of traffic started to grow and the amount of cargo transportation via Finnish ports increased by 13% compare to 2011 [3]. In 2012, it continues to grow with decrease in import transport volume by 10% and increasing export transport volume by 0.5% compared to the year of 2011 [12]. Therefore, it is noticeable that shipping activity in the Baltic Sea is a growing area, even though there are significant changes in trade volume. **Figure 5** shows Finnish foreign trade volume (including dry cargo and liquid cargo) with other countries on the Baltic Sea Region, which also indicates the importance of this route to Finland. Russia, Sweden and Germany being the strong trade partner for Finland along with other Baltic states. The main source for the growth in trade volume is the material flow from Russia while the Swedish Merchant fleet is declining, thus offering opportunities for Finnish shipowners [13].

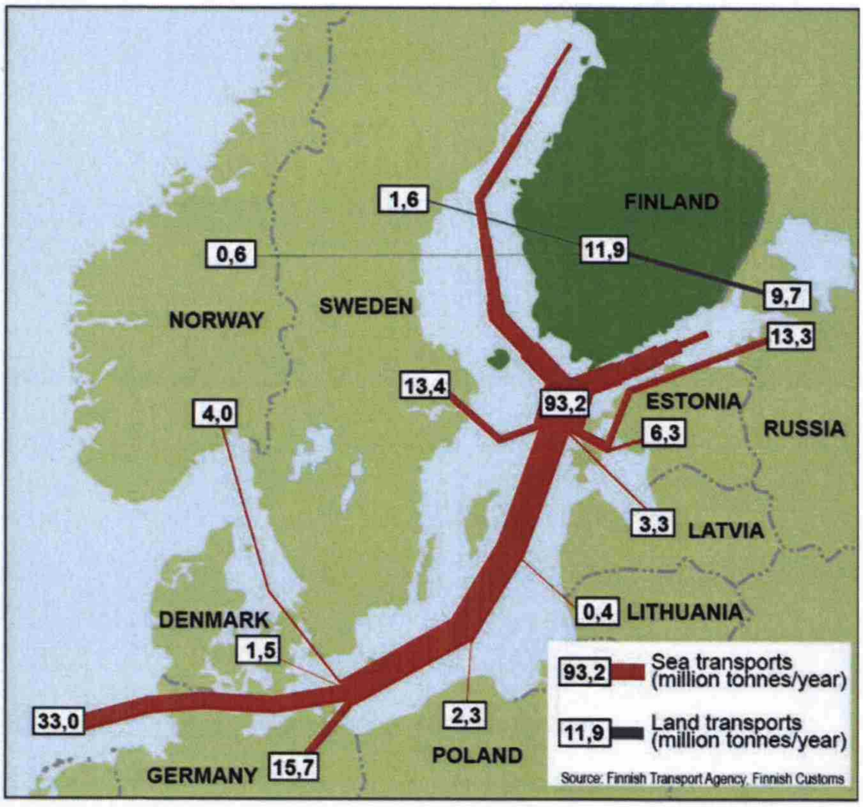


***Figure 5** Finnish foreign trade transports (including transit transport 7.1 mill. tonnes) in 2012 and countries of destination (source: Finnish Transport Agency, Finnish Customs)*

Finnish seaborne commodities can be grouped into three main categories; dry bulk, liquid bulk and other dry cargo. It can be seen from **Figure 6** that Other dry cargo forms the biggest cargo type in Finnish international maritime traffic (39%) followed by dry bulk (32%) and liquid bulk (29%) in 2011 [3].

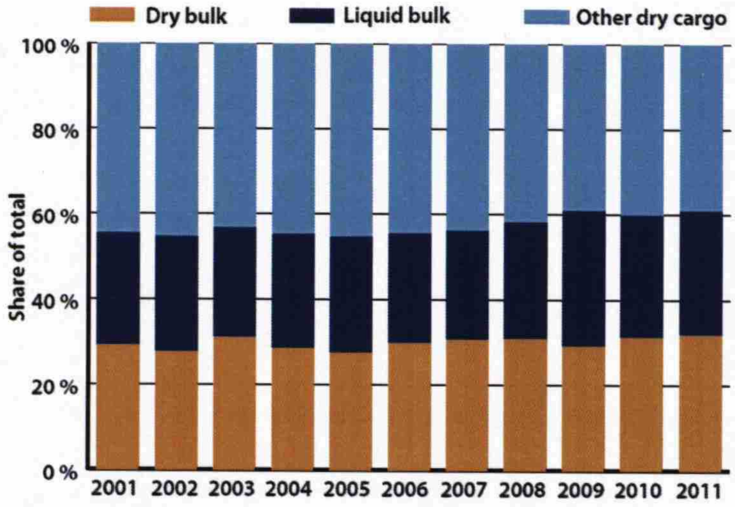
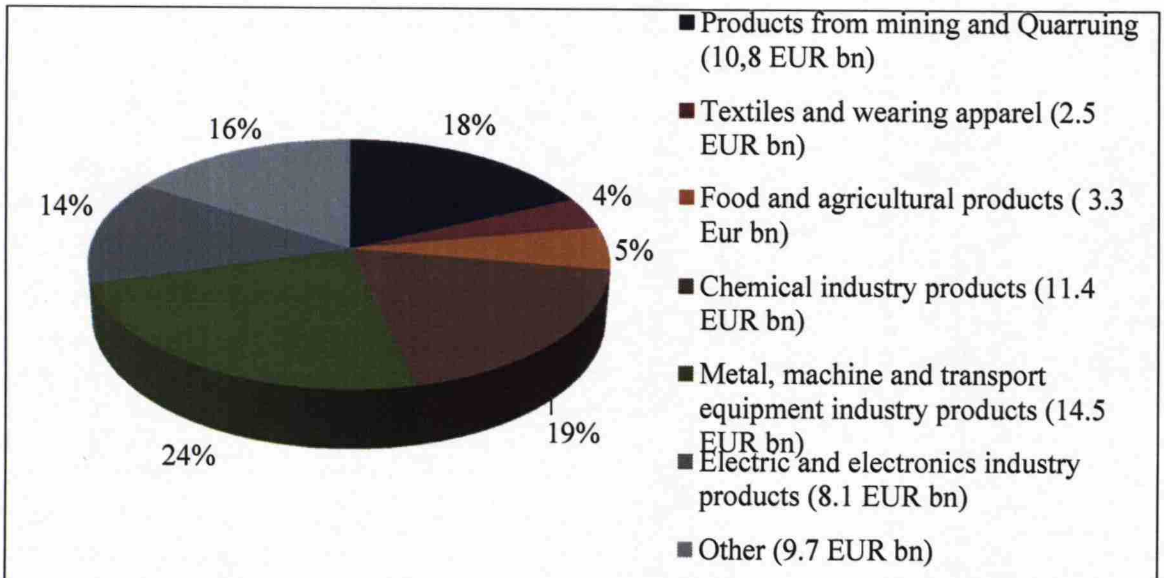


Figure 6 *Finnish Cargo type distribution in 2001-2011 [3]*

The trend of changes in cargo type distribution indicates a decrease in percentage share of other dry cargo in recent years while the opposite is experienced for Dry bulk and Liquid bulk cargo.

3.1 Import

In 2011, Finland´s major import trading partners consisted of Russia (27% share), Sweden (16% share), Germany (11% share), Latvia (8% share) and Estonia (7% share). Over the period 2001-2011, all the main trading partners have increased their volumes shipped to Finland [3]. Russia has increased its volumes from 4.6 million tonnes in 2001 to 14.6 million tonnes (+219%) in 2011 due to increasing transportation of oil [3]. Most of the major industries in Finland are very much dependent on imported raw materials or other supplies and the rate of import dependency varies between each sectors.



Imported cargo share of Finland in 2011 (source: National Board of Customs)

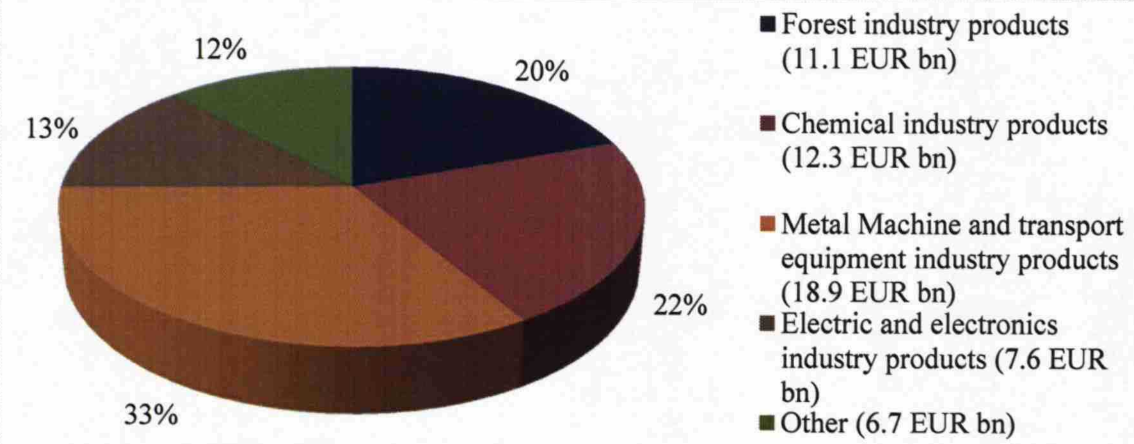
National Emergency Supply Agency (NESA) has defined critical industry and their import goods as follows:

Table 1 *Critical industry sectors and their imports [14]*

Critical Industry	**Main imported goods and materials**
Energy	Oil, gas, uranium, coal
Food Sector	Pesticides, fertilizers and their raw materials, animal feed, agricultural machinery, chemicals, packaging materials
Health care	Pharmaceuticals, equipment, basic chemicals
Forestry industry	Timber, fillers, coating pigments
Chemical industry	Crude oil, basic chemicals, rubber
Technology industry	Components and parts, metals, minerals, fuels

3.2 Export

In 2011, Finland´s major export trading partners consisted of Germany (21% share), Sweden (15% share), the Netherlands (13% share), Great Britain (7% share) and Belgium (7% share) [3]. Over the period 2001-2011, Finland has managed to increase its exports to Sweden and the Netherlands only (Finnish Transport Agency).



Finnish Export by product group in 2011 (Source: National Board of Customs)

Finland exported 44.3 million tonnes of commodities in 2011. The main commodities volume wise exported comprised of metal, machine and transport equipment, paper and paperboard, oil products and general cargo as shown in the chart above. These commodities were followed by ores and concentrates, chemicals, sawn wood, wood pulp and electronics industry products. The top three commodities alone accounted for 50 per cent of total export volumes [3]. Export industry plays vital role to the Finnish economy as in 2011 the value of total export cargoes increases.

3.3 Changes in Finnish industrial sectors

Finnish industrial and logistics sectors are undergoing a structural change; therefore, to ensure future profitability and sustainability of the business positions, it is necessary to adopt efficient strategies. Geographical location and climate effect on logistics weakening Finland's economic competitiveness compared to other countries. Future Finnish industry and logistics are anticipated to be affected by several factors, such as energy efficiency, control of environmental effects, growing automation and developing technology, rising logistical cost and concentration of international ownership [15]. New complexities regarding the change in material flow makes it more difficult to forecast about the future trade situation. However, effective planning and increasing the interaction among different industry, shipping company and shipbuilders can mitigate the risk for future.

Finnish economy is very much dependent on the development and success in foreign trade and relies on three principal industrial sectors; technology industry, chemical industry and forest industry [3]. At the same time, import of raw materials directly affects the export volume. In the recent years, Finnish import volume of goods are growing larger than export volume [3]. In order to justify the need of Multipurpose Vessel for the future as a mode of dry cargo transportation, next section discuss about the structural changes and potential cargo flow from major Finnish industry segments: Metal and mining industry, Forest Industry, Chemical Industry, Technology industry and Wind power energy segments.

3.3.1 Metal and Mining Industry

Metal and mining industry is regarded as a group of industry that extract, process or refine minerals, metals and other materials [16]. Being a mining-friendly country within the EU together with an excellent geodata and infrastructure, a favorable and secure investment opportunity for Finland is developing. The vision of Finland's mineral strategy for 2050 is to become a forerunner in sustainable exploitation of minerals and global leader in green mining [17]. Several new mines are planned to be established in northern and eastern Finland which will be opened in 2015 and onwards [17]. **Figure 7** shows the Finnish mining vision for 2020 which is forecasted based on statistics by the Ministry of Employment and the Economy (1968- 2008) and Geological survey of Finland (GTK).

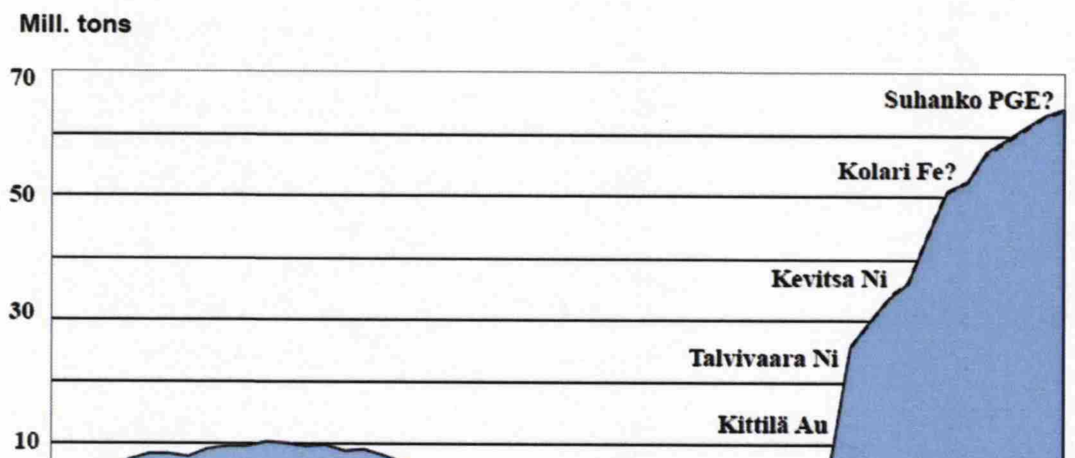


***Figure** 7 Ore exctraction from Metal mines 1968 -2020(forecast)-Source:GTK*

It can be seen that the mining is going to be approximately 2- times higher in 2020 than in 2012. Maija Uusisuo (Branch Manager for Mining and Stone Industry, Regional Council of Lapland) has estimated that the metal ore production will be doubled in 2020 compared to 2012. But at the same time, the amount of left over rock will increase per ore volume and cost of mining will increase as well. Leftover rock is produced as a process of dilatation which should be minimized.

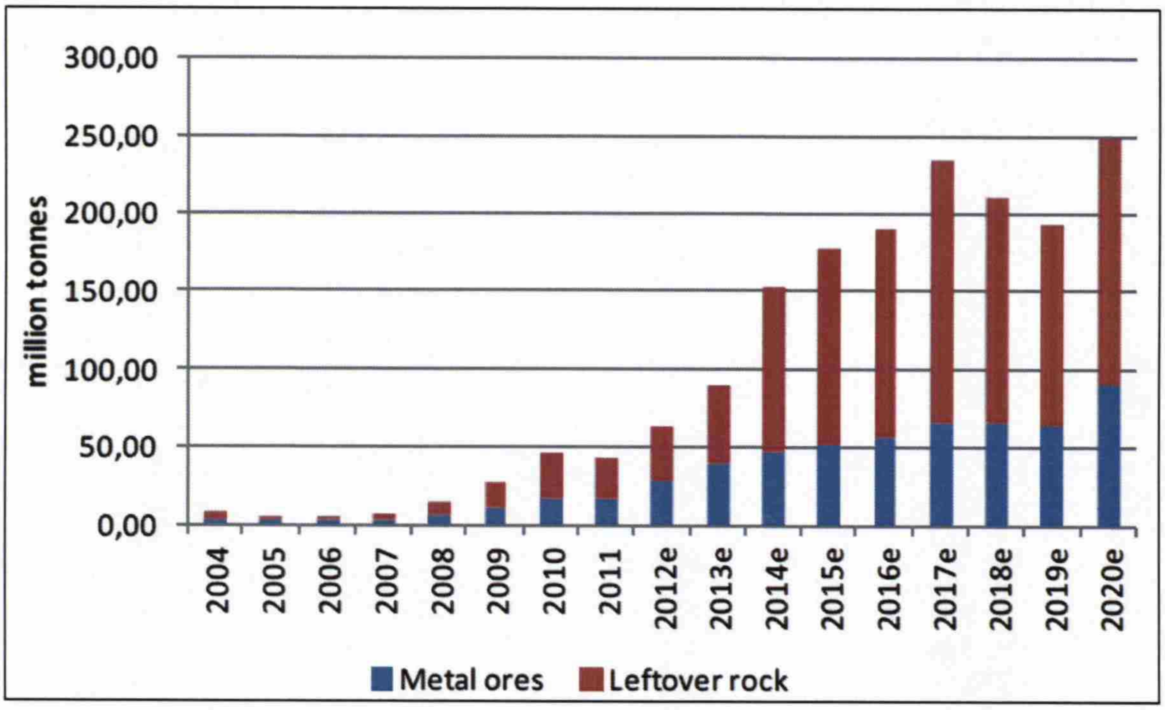
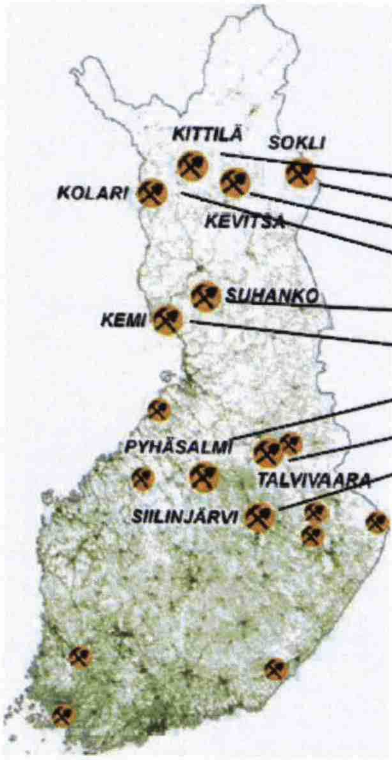


Figure 8 *Estimate of metal ore mining (Uusisuo, 2012)*

The new mining project will not only boost the Finnish economy but also provide employment opportunity for the large number of population (**Figure 9**). However, there is also an increasing concern over the negative environmental impacts that are creating pressure on mining companies to develop and use greener technology for mining in the future.



Main commodity	Estimated Revenues (Mill. €/a)	Employees
Gold	200	500
Phosphorus	120	250
Nickel	150	250
Iron	200	200
Palladium	150	250
Chrome	200	300
Copper	120	220
Nickel	800	600
Phosphorus	120	250
Others	900	1200
Total	2960	4020

Base map: population density

Figure 9 *Finnish mining vision in 2020 (source: GTK)*

The largest operating metal and steel industry companies are located along the coastal areas, such as Ruukki Steel Production Plant in Raahe and Outokumpu in Tornio. Outokumpu plans to double its ferrochrome production volume this year, 2013 [3]. But the steel industry is sensitive to the economic fluctuations and largely depends on Chinese and Indian demand. The financial crisis had its impact on Finnish steel production which can be seen from **Figure 10**. Due to the economic recession in 2008 global demand and investment for steel production have decreased, thus lowered the Finnish steel production in 2008-2009. However, based on the last few decades' statistics of steel production, it is forecasted in excel which shows to have stable growing production scenario in the future.

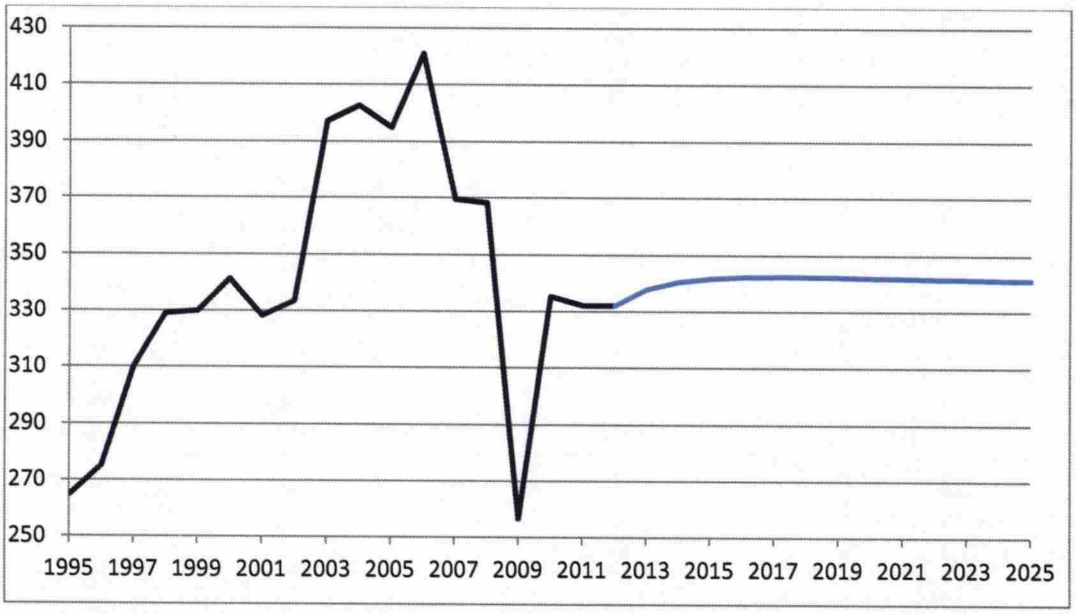


Figure 10 *Average of Finland's Steel Production '000 tonnes (Modified forecasted data from Clarkson.)*

However, the metal and mineral market's volatility is expected to continue rising in the future, mainly caused by the increased political risks, taxes, fluctuations in prices and mining costs [16]. At the same time global population growth and urbanization will increase the use of metals and minerals. Developing countries growth strongly affects the need for metal and minerals. It is expected to increase the export of late and middle cycle refined metals and minerals whereas the import of raw material will be substituted with domestic production [16]. Maximum transport capacity will be demanded from the metal and mining industry in the future.

3.3.2 Forest Industry

Forest industry is another major industry for Finland which is undergoing a structural change in attempt to safeguard its competitiveness. About 68% of the total surface area of Finland is covered with forest which lays the foundation of economic and social sustainability [18]. This industry can be divided into three segments: production of paper and paperboard pulp, and wood products. Development of Finnish commercial fleet and shipbuilding industry is based largely on the export of paper and forest industry products in early days. However, the industry's production capacity has been reduced by 20% in comparison to 2005's level mainly because of significant reduction in wood pulp production [3]. Finnish forest research institute forecasted that the pulp and paper industry production volume will decrease by up to a third and the wood processing production by just a fifth in 2020 compare to 2007 production level (**Figure 11**).

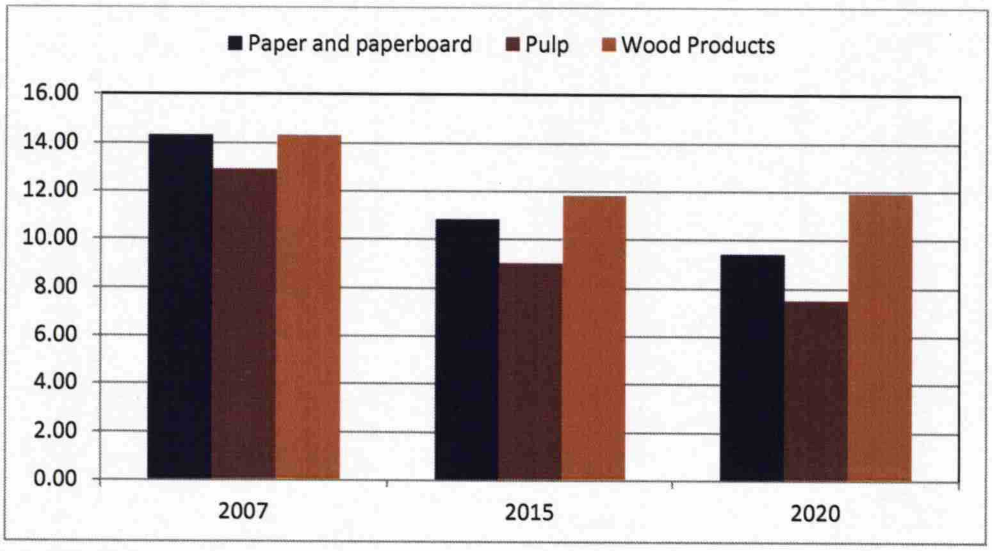


***Figure 11** Finnish forest industries production in 2007 and Outlook for 2015 and 2020 (mil. tons and mil. m^3) [19]*

There are several factors active behind the weakening of export volume from forest industry. Due to the overcapacity of paper machines and weak paper price development in Europe, some of the paper factories are forecasted to shut down in the near future. Structural changes in electronic communication and publishing media lowered the paper demand as well. Increasing competition over price of paper production with Asian country (like China) causing the export volume down for the paper industry. However, wood product consumption is forecasted to be increased in Finland's main export market in the EU but it will happen very slowly. This segment will have tight competition with Russia and Germany because of their low production costs [20]. The pulp industry mainly depends on imported wood and due to Russian round wood export taxes, the amount of wood imports to Finland have been decreasing. However, demand for plywood is growing for LNG carriers in the Asian market because of the advantages in insulation purpose in such vessel. Finnish forest research institute also forecasted that by 2020 the saw and plywood industry would produce more wood chip and saw dust than the pulpwood industry [18].

Finland has taken the renewable energy targets very seriously and the most important renewable sources of energy are bioenergy (wood based fuels). Wood chips production will increase as it is targeted as the main source for the renewable energy [21]. Therefore, focus of the future forest industry is likely to be found in "renewable forest industry" including biofuels, bio-composites and e.g. nanotechnology-based applications and products which are recyclable and used as biofuel at the end of product's life cycle [3].

3.3.3 Chemical Industry

Chemical industry is one of the three major industries of Finland, having a growing state in nature. This industry is mostly dependent on imported raw materials like crude oil and industrial chemical materials. Principal industrial customers are represented by forest industry, transport, electronics industry, metal industry and construction. Principal product groups include pulp and paper industry chemicals, petroleum products, fuels and lubricants, plastics, packaging and precision plastics, paints, plastic piping systems, as well as damp-proofing and thermal insulation materials. Products are manufactured into a variety of intermediate industrial and consumer, and product applications [22] .

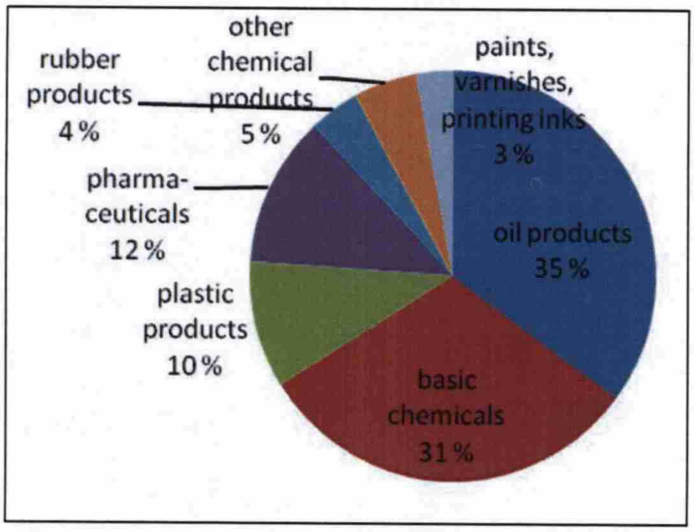


Figure 12 Main commodity groups exported by the Finnish chemical industry -2009 [23]

Although in terms of gross value of production, chemical industry have strong contribution in Finnish economy; during last decades significant changes have been found in this industry. Special chemicals, plastic products and composites have increased their shares compared to standard chemicals. As chemical industry is an energy intensive sector, therefore, rising energy and raw material prices have shifted the production to low-cost countries including Asia and the Middle-East. It also contributed to the shifting from oil-based chemical production to the use of cheaper raw materials. On the other hand, bio raw materials will compensate the use of oil and gas. Finnish chemical industry sees potential and business opportunities in the product, technology and process innovations, associated with climate change control and scarcity of raw materials [3]. The focus of chemical industry is in increasingly processed end products, systems and services, thus potentially resulting in smaller transport volumes. In recent report of Laiva 2025 project, it is forecasted that the production from chemical industry will remain at the level of 2012 in 2025 [3]. There will be two kinds of companies that will succeed in the chemical industry in the future - focused specialist and integrated players [24]. Finnish companies have potential to succeed as focused specialists, if they have superb application or product technology knowledge [16].

3.3.4 Technology industry

Technology industry composed of several industry segments but mainly electronics and electrical engineering industry, machine and metal product industry, consulting engineering, information technology poses significant role to the economy. The turnover of technology industry companies in Finland was EUR 67.6 billion in 2012 while in 2008 the amount was EUR 81.4 billion; therefore, due to financial crisis personal number also drop from 321,000 in 2008 to 289,000 in 2012 [25]. **Figure 13** shows the percentage of export Goods in 2010 which also indicates that products from Metal Industry and Machinery Industry holding the maximum percentage of total volume.

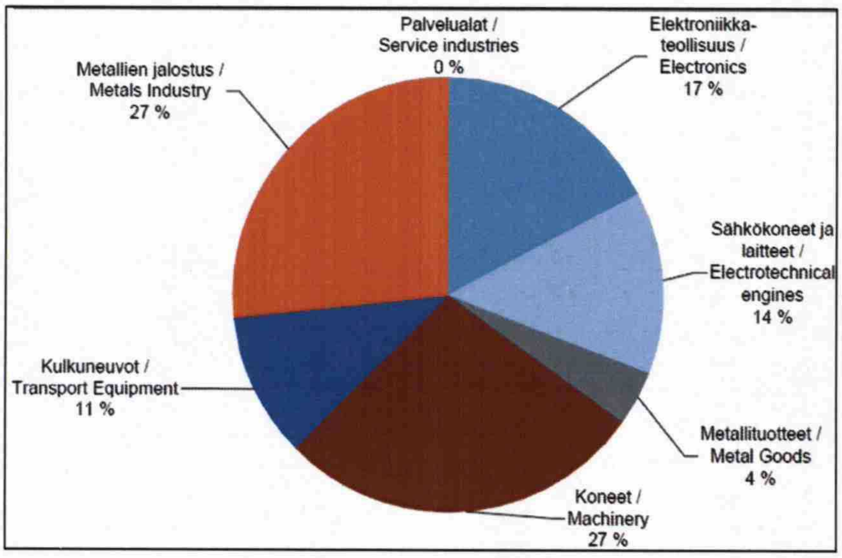


Figure 13: *Structure of the Technology Industry Exports of Goods in 2010 (Year book 2011-Teknologia Teullisuus)*

There is also undergoing structural change in Technology industry. Focuses of manufacturing companies have altered because of manufacturing cost difference in Finland and Asia. The availability of reasonable-priced energy also threatens to become an investment bottleneck for

Finland [26]. Fundamental change in machine industry has already made by changing the focus as shown in **Figure 14.**

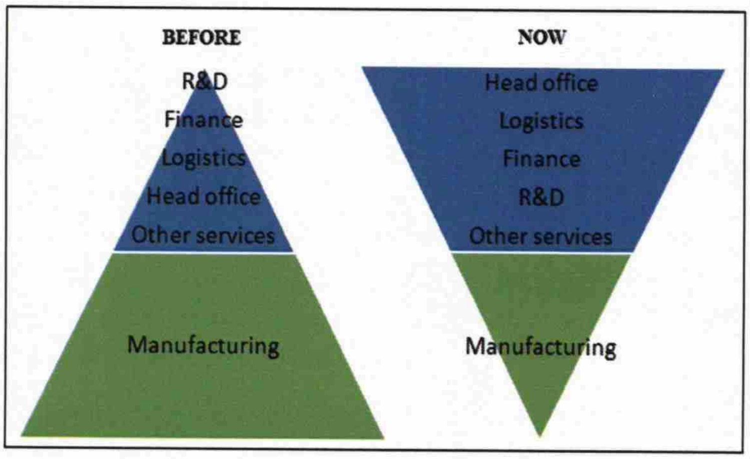
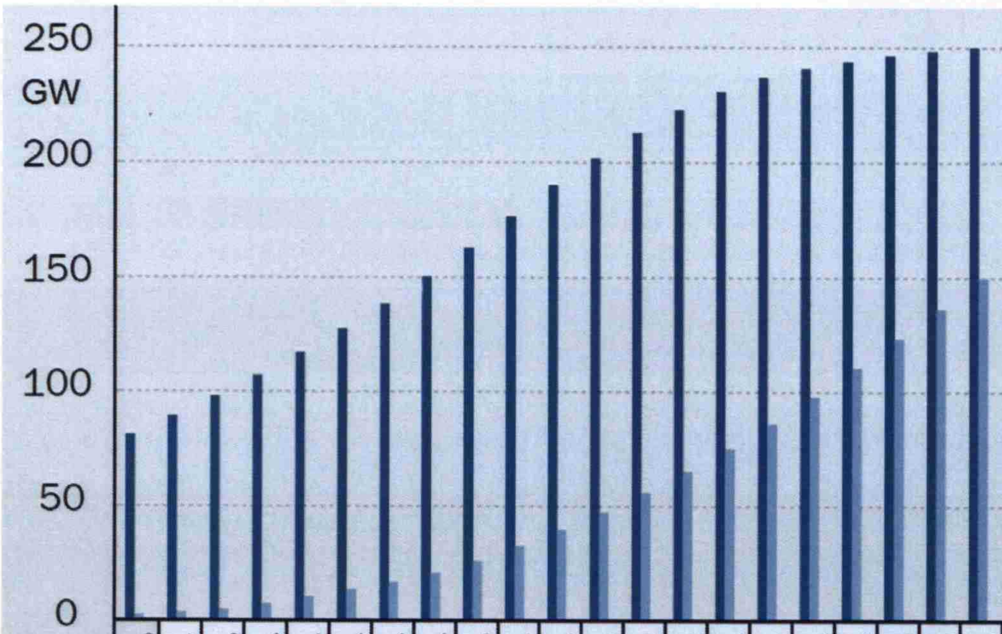


Figure 14 *Focus of manufacturing companies before and now. (Pajarinen, Rouvinen, & Ylä-Anttila, 2012)*

The volume of Finnish manufacturing industry production is likely to decrease in 2025 because of changing the focus from manufacturing to R&D, sales and other supporting functions. At the same time, reduction in investments causing decrease in production volume of the technology industry. Combating the climate change will also increase the cost of production compare to competitor countries but it will also offer to develop and focus on new environmental and energy technology. Machine industry will continue to have great prospects among other technology industry segments in the future and company like ABB, kone, Metso, Wärtsilä and others will remain big player for this industry [26].

3.3.5 Wind Power Energy Sector

Even though wind power energy sector is a part of technology industry, as renewal energy is going to dominate the industry in the near future, extra emphasize is given for Wind Power production sector in this thesis. The usage of renewable energy sector is growing market for future as EU have given special concern to expand the energy production in wind powered production. Installed wind power capacity in EU totaled is 105 GW (Gigawatt) in total in 2012 [27], while the European Wind Energy Association (EWEA) expects to have 400 GW wind energy capacity consisting of 250 GW on land based and 150 GW offshore based wind farms by 2030 which will produce 28.5% of electricity demand in Europe (1,154 TWh) [28] (**Figure 15**).



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Onshore	81.4	89.6	98.0	107.1	117.0	127.5	138.6	150.4	163.0	176.4	190.0	202.0	213.0	223.0	231.0	237.0	241.0	244.0	246.5	248.5	250.0
Offshore	2.9	3.9	5.3	8.1	10.9	14.0	17.4	21.6	26.7	33.1	40.0	47.7	56.2	65.5	75.6	86.5	98.1	110.4	123.2	136.4	150.0
Total	84.3	93.6	103.3	115.2	128.0	141.5	156.0	172.0	189.7	209.5	230.0	249.7	269.2	288.5	306.6	323.5	339.1	354.4	369.7	384.9	400.0

Figure 15 *Cumulative onshore and offshore Wind power in the EU (2010- 2030) source: EWEA*

Currently, Germany is the country in EU with the largest installed capacity, followed by Spain, Italy, UK and France [29]. Finland is also committed to EU target to increase the use of renewable energy from 28.5% to 38% by 2020 compare to 2005 [30] (**Figure 16**).

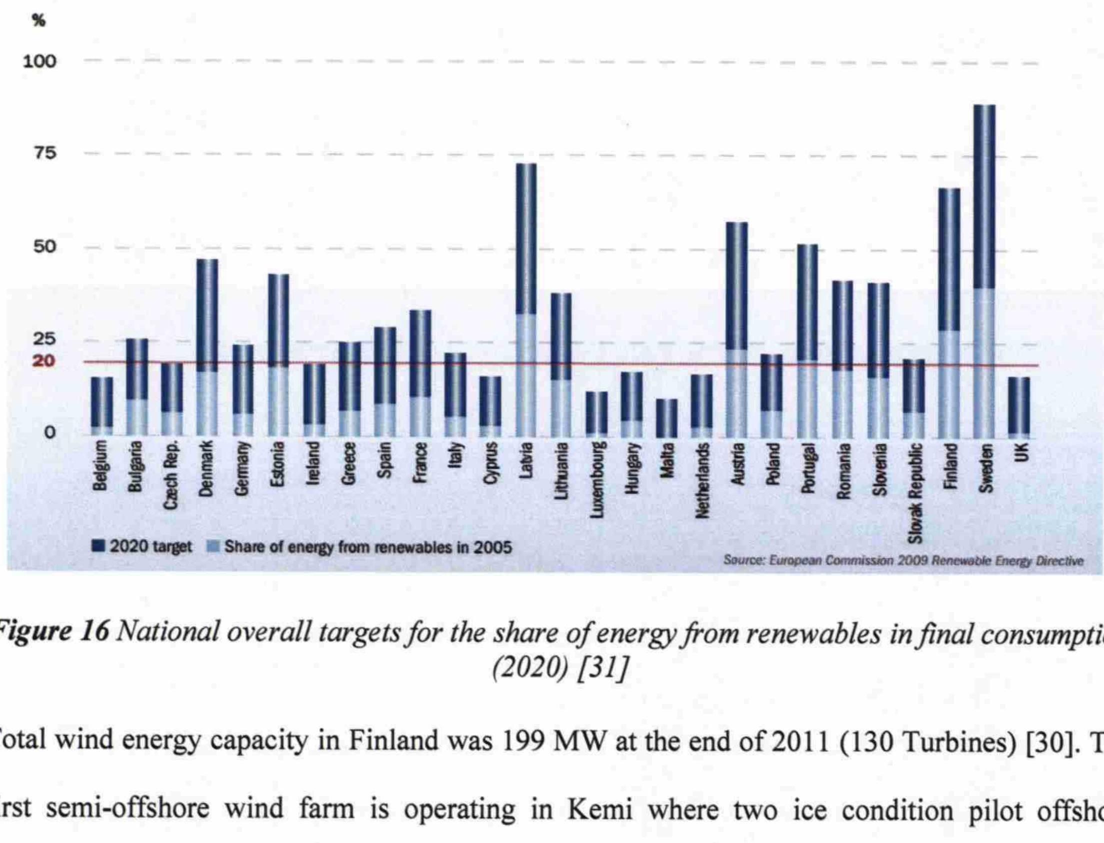


Figure 16 *National overall targets for the share of energy from renewables in final consumption (2020) [31]*

Total wind energy capacity in Finland was 199 MW at the end of 2011 (130 Turbines) [30]. The first semi-offshore wind farm is operating in Kemi where two ice condition pilot offshore projects are on-going since 2010 [30]. Key statistics of Finnish wind power energy in 2011 can be seen below:

Table 2 *Wind power energy -Key Statistics 2011: Finland [32]*

Total installed wind generation	199 MW
New wind generation installed	2 MW
Total electrical output from wind	0.48 TWh
Wind generation as % of national electric demand	0.6%
Average capacity factor	28%
Target:	6 TWh/yr (2,500 MW) in 2020

Finnish government has the target to build 900 windmills to produce targeted 2,500 MW power from Wind and therefore about 3.5 billion Euros will be invested by 2020. [27]. This will make wind powered energy as the second largest source of renewable energy in Finland which will also create new employment opportunity as well [32]. However, achieving this target will not be really easy because of technical challenges, aviation, military regulation and political problems [27].

Finnish wind power technology industry is strongly export-oriented and in the year of 2011 the export value was approximately 1 billion EUR (mainly components, material, wind turbine) [30]. The construction of wind power plants is booming all over the world. There is going to be joint collaboration with German wind developer WPD and the STX Turku shipyards, where Turku shipyard could make offshore wind turbine foundations for WPD [33]. Wind turbine manufacturing company like WinWind, Mervento, component manufacturer like ABB, Oliatalo, The Switch and other related companies are looking forward to maximize their export volume [32]. These also demand the development of transport system mostly for sea transportations that are usually needs for install and operate wind farms comprise of multiple crafts such as wind turbine installation ships (WTIS) and multipurpose cargo/deck carrier which is capable of transporting project cargo.

3.4 SWOT analysis of Finnish Maritime Industry

Based on previous studies and further research, a SWOT analysis is made on the current situation of the Finnish maritime industry. This was basically done following the findings of the PBI Research Institute with modification [34]. **Figure 17** shows the outcome of the findings in modified version.

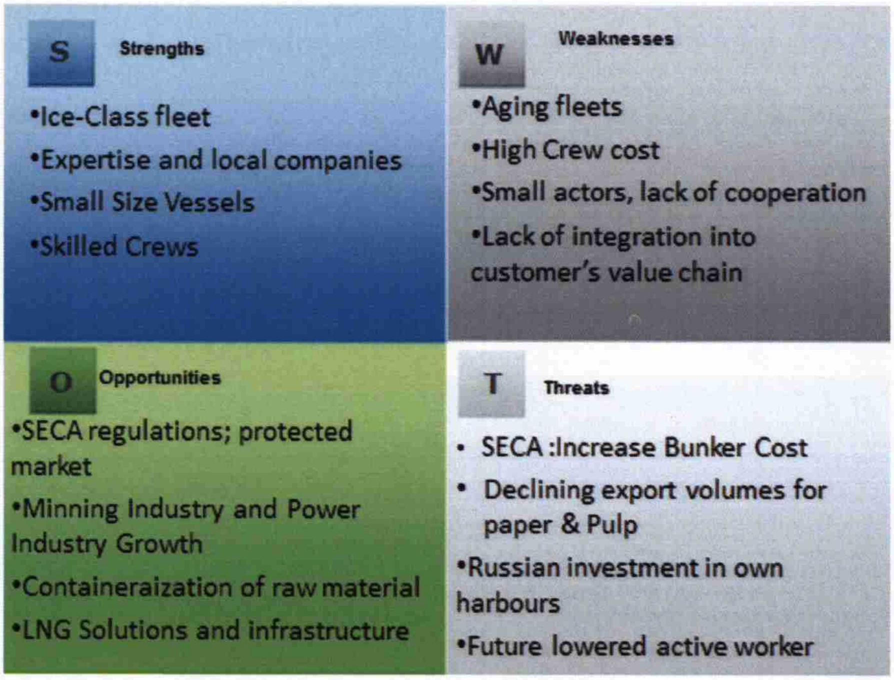


Figure 17 *SWOT analysis of the Finnish shipping [34] (Modified)*

Main strength of Finnish shipping is their ice strengthened vessels which are capable to operate efficiently in ice conditions. Along with skilled crews, local customers found Finnish expertise and local companies as more reliable than foreign ones. Average Finnish flag vessel size is small which helps during short-sea operation, going directly to the harbors but future vessel is going to be larger in size because of more energy efficiency and profitability.

Ageing fleets is found to be the threatening and demands to replace with newer vessel to comply with future environmental regulation in the Sulphur Emission Control Area (SECA). High crew cost is also making the operational cost higher compare to foreign flagged vessels. Major weakness is the lack of cooperation between small Finnish actors which leads to low capacity utilization of vessels thus making less profits. So, the interaction and collaboration with each of the shipping industry player should be increased and integrated more to obtain higher capacity utilization of the vessels [34].

Operational cost of vessels will be higher in the Emission Control Area (ECA) but at the same time opens an opportunity for Finland as it will create protected market in the Baltic area, making foreign ship operators uninterested. Thus, developing better solution like LNG usage and infrastructure development will be beneficial for Finland. In future, mining, wind power industry and amount of biofuel shipments will increase from Finland and continue to grow shipping activity in the ECA. Containerization of cargo is increasing globally and the future vessel should be capable of carrying more containers. High number of different type of cargos, even the raw materials are increasingly transported in containers providing an opportunity also for Finland to develop container oriented multipurpose vessel.

Decreasing amount of cargo flow from Finnish paper and pulp industry can be seen as biggest threat for Finnish shipping industry. On the other hand, Russians are making investment on their own ports and terminals showing a tendency to control the whole logistic chain which could eventually reduce the transit and feeder traffic. Another threatening factor would rise as in the future lower number of active workers will be present. As a result, more emphasize should be given on increasing automation to reduce human dependency and operational cost [34].

4 Possible Future Cargo flow on Northern Baltic Sea

The Baltic Sea area will continue to be crowded with increasing number of maritime services which will double the number of ship by 2030 with an increase in vessel size [35]. Maritime cargo volume is forecasted to increase about 30 percent by 2030 among the ports along with the Baltic Sea coast while Russia will occupy the largest cargo volume share followed by Sweden, Finland, Denmark and Germany [6]. Changes is anticipated in the structure of cargo type distribution comprising liquid bulk, dry bulk, Ro-Ro cargo, containers and other cargo by 2030 as shown in **Figure 18**. Liquid bulk will experience a decrease in share volume while containers, share volume are expected to increase. Among individual cargo types, container transports are forecasted to grow the most in the Baltic Sea ports by 138 per cent in 2030 while Ro-Ro cargo and Dry bulk is also expected to grow by 51% and 42% respectively [6].

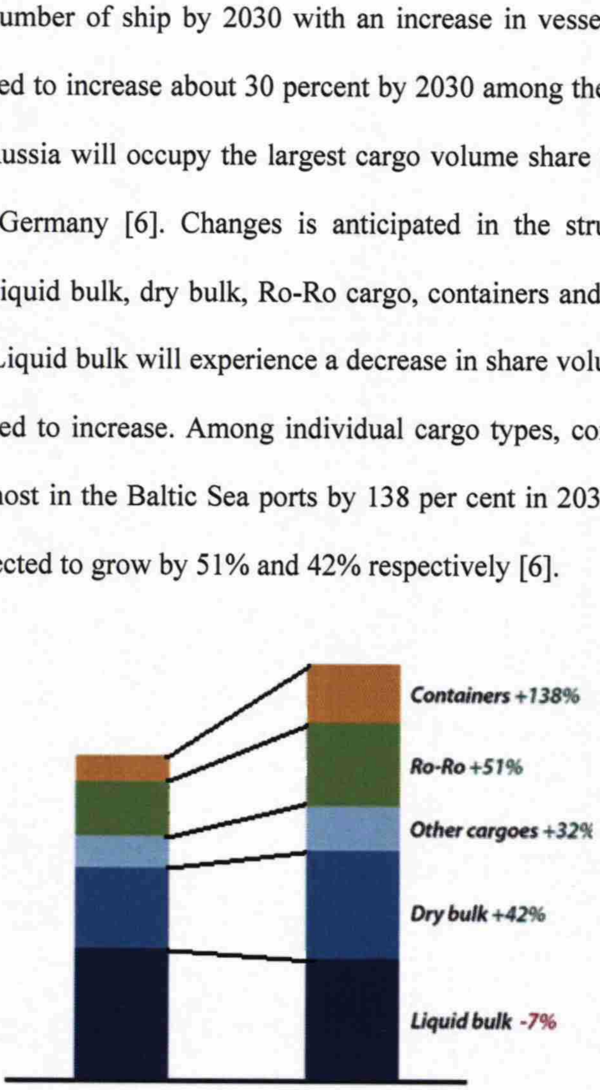


Figure 18 *Maritime transport forecast by cargo types in the Baltic Sea region in 2010 – 2030 (Source: Baltic Transport Outlook 2030)*

However, only three Baltic Sea countries out of ten is expected to exceed the average relative growth of 30 percent for the entire Baltic Sea region, in 2030 [6]. The strongest relative growth is expected in Poland, Russia and Sweden. The relative increase for Finland is forecasted to be 27%, increasing the international seaborne traffic volume from 98.4 Mt (2010) to 125.3 Mt (2030) [6].

4.1 Future Import and Export Cargo flow –Finland

Finnish export and import trade will experience changes in volume share as discussed in the previous chapter. In spite of the changes, both export and import cargo flow will demand higher transport capacity on Northern Baltic Sea. **Figure 19** indicates the major export cargo flow may occur in the future from Finland and the size of the bubble indicates the probable market share size.

***Figure 19** Possible future Export cargo type from Finland*

This is done based on the study made in previous chapters and world seaborne trade condition and trends. The exact percentage of volume change for each cargo type is not possible to determine at this stage but can be understood the reduction or increment based on industrial change. In recent years, import cargo volume exceeds the export volume for Finland [3]. **Figure 20** shows the main import commodity of Finland which will dominate the trade on the Baltic Sea.

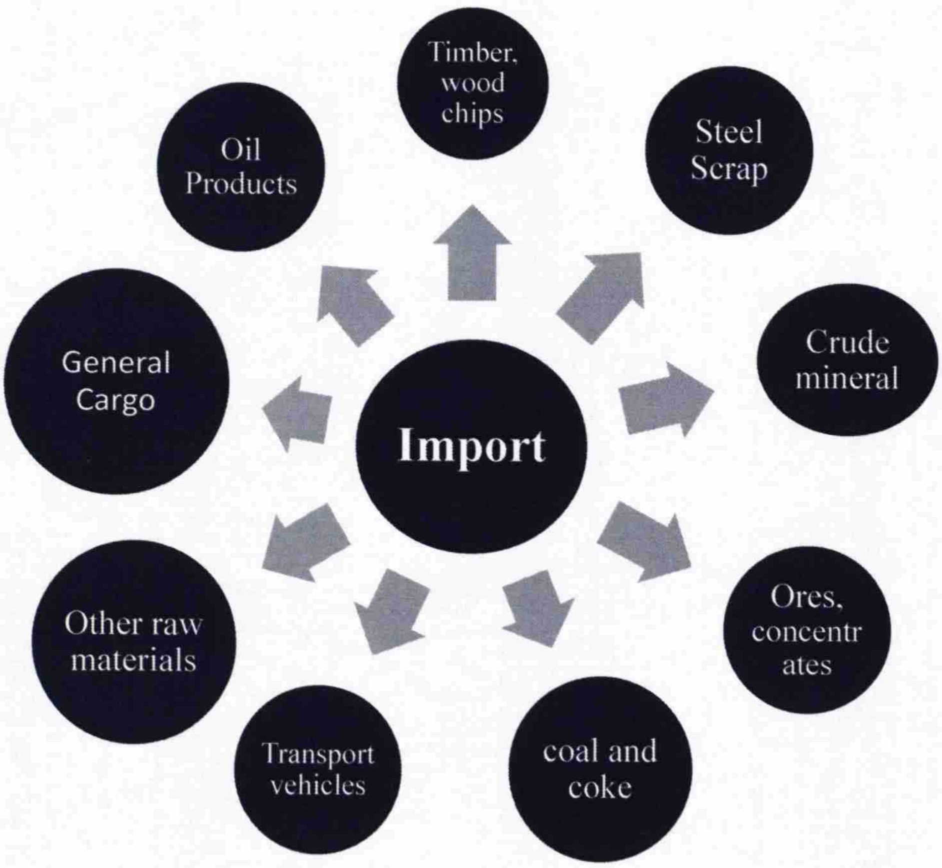


***Figure 20** Possible future Import cargo type to Finland*

Most of the export and import commodity in the future will be related to metal and mining industry because of big investment plan and demands in developing countries while shares of electro-technical industry and forest industry will be reduced.

4.2 Future Ship Type and Technical Challenges

Maritime transport system is composed of maritime shipping and the ports dimensions which keep changing to maintain better sustainability and efficiency of the business model. This changing occurs mainly because of six major influencing factors like Finance, Policy, Demography & Society, Economics, Energy & Environment and Technology which is described in **Figure 21** [36]. Maritime shipping is highly globalized industry; therefore, any change in supply and demand of cargo outside EU affects the transportation system on Baltic Sea.

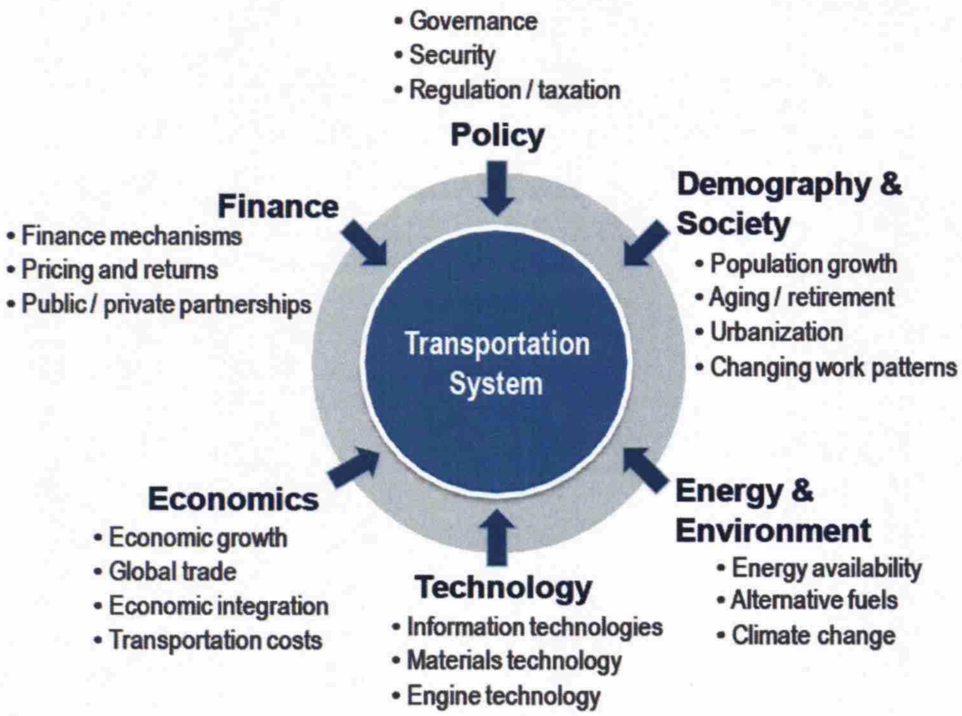


***Figure 21** Drivers of change for Future Transportation (source: ICF International -2008)*

Based on the industry trends for the entire six factors, it can be seen that future cargo flow is not homogeneous in nature and future shipping is becoming more challenging and unpredictable. So, a vessel capable of carrying different type of cargo throughout its operational lifetime will be more feasible in the future shipping business. Therefore, the need for container oriented multipurpose vessels will increase in the future shipping industry. These ships should consider long term strategy against possible redundancy in a modally changing market thus require standardization of the vessel specifically suitable for the Northern Baltic Sea route.

There will be numerous challenges for the future multipurpose vessel considering the upcoming regulations for greener environment and pollution control. Baltic Sea has drastically changed over the past decades due to large number of vessels in operation on this route which have polluted water and emitted high scale of CO_2, SOx and NOx. To improve the situation, Baltic Sea is defined as a part of the Emission Controlled Area (ECA) and designated for controlling SOx and PM or NOx or all three types of emissions from ship [2]. **Figure 22** shows the set of rules and regulations which are going to shape the shipping industry towards the greener shipping. From the beginning of 2013 Energy Efficiency Design Index (EEDI) for Ships came into force which applies to all ships greater than or equal to 400 Gross Tonnage. This EEDI is also applicable to any ship contracted later than 1 January 2013 or keel-laid later than 1 July 2013 or will be delivered after 1 July 2015 [37]. In the Emission Control Areas (ECA), from the year 2015, no more than 0.1% Sulphur content in fuels or equivalent EGCS (Exhaust Gas Cleaning System) is allowed for all ships. Ships those will be built after 2021 operating in ECA's have to comply with NOx Tier III which demands 75% reduction of NOx emission than the currently applicable global Tier II NOx emission [2]. Even though it was supposed to implement from 2016, Russia asked to postpone the implementation of NOx Tier III until 2021 which will substantially affect the shipping business plan as well.

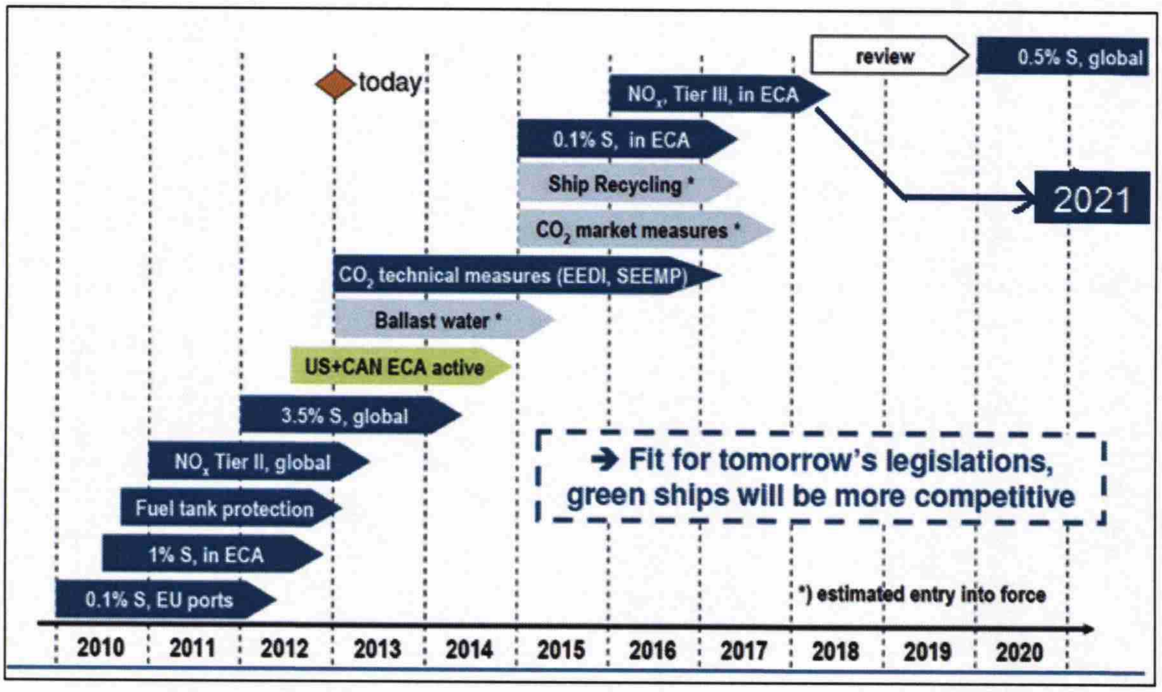


Figure 22 *Timeline for environmental legislations (source: Germanischer Lloyd)*

According to a report of DNV, it is estimated that about ten years will be needed to replace 25% fleet in the Baltic Sea [2]. Thus, approximately 75% of the current fleet will be in active operation in 2025 and those vessels have to comply with all upcoming future environmental regulations. To comply with these regulations, these vessels currently in operation in the ECA have to switch compliant fuel system from HFO to MGO which is also an expensive solution [38]. However, the availability of low Sulphur fuel is limited and the increasing demand of such fuel will raise the fuel price as well. Another solution to the existing vessels could be installation of scrubber. Scrubber systems are a diverse group of air pollution control devices to remove Sulphur from the engine exhaust gas by using chemicals or seawater and this system will require significant alteration of the vessel. Thus, scrubber is suitable for newer vessels in operation as these vessels will be able to repay the investment cost before the end of their commercial life. A study made by Baltic International Maritime Council showed that a ship that operates in the ECA zone 33% of the time, should have 10 years of commercial life left to achieve positive net present values of its scrubber investment [39]. Therefore, higher modification cost and increase in operational cost due to the increasing fuel price, large amount of older vessel will ultimately be scrapped from 2015 which will surely create opportunity for newer vessel but at the same time will create turbulence in the freight market. For the newbuildings, bio-fuel is showing growing interest but the use of such fuel is still marginal. Therefore, LNG – Liquid Natural Gas regarded as the best environmental friendly and economical solution for future which is already been tested and proven on many ships. New ships with LNG fueled propulsion solution typically have an added investment cost of 10-20% which is mainly because of special LNG storage tanks and piping system [2].

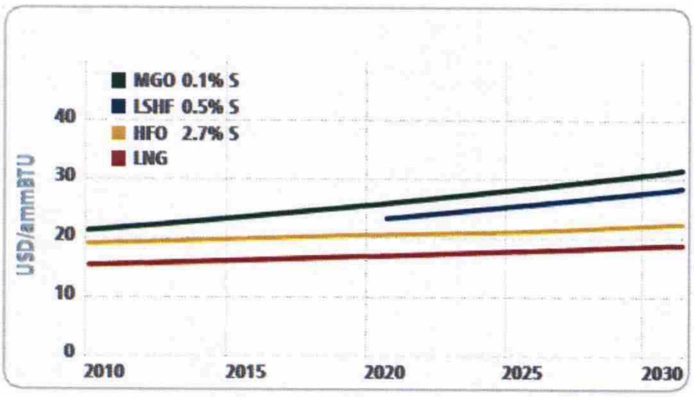


***Figure 23** Fuel price scenario (source: Germanischer Lloyd)*

Figure 23 shows the price development of Marine Gas Oil (MGO), Low-Sulphur Heavy Fuel Oil, Heavy Fuel Oil and LNG along with the Sulphur content in these fuels and it can be seen LNG will be the most economical fuel for the long run. Along with the usage of LNG as main fuel, alternative powering like utilizing wind power, solar power can be additional power sourcing option for future ship.

Therefore, if shipowners knew the ship requirements of 2040, as the ship built today likely to be in operation for next 25 to 30 years, the current ship investment would be much easier. [16]. At this moment, operational costs for different type of ships are increasing and will continue to increase due to various new rules and regulation concerning environmental pollution control. As it is predicted that future markets will be more volatile and product cycles will be shorter than before to meet the future supply and demands, throughout the ship's 25 or 30 years life cycle the transportation requirements might be changed many times. Thus, it seems that vessels that are capable to carry different cargo types and container oriented e.g. LNG powered multi-purpose vessels might fulfill the industry needs in 2025 [16]. So, for sustainable future it is needed to develop a standard series of MPV suitable for Baltic operation by combining optimum hull design, machinery arrangements and fuel system that can carry versatile cargo transportation throughout its life time.

5 Multipurpose Vessel and its Markets

As concluded in the previous chapter that multipurpose vessel will be the most suitable vessel for the Baltic Sea in the future, in this chapter, general characteristics, design trends, future technology regarding multipurpose vessel, MPV market condition, Trade, fleet development and competitive threats for this market segment will be discussed.

Multipurpose Vessel (MPV) is a kind of vessel that can carry different types of cargo at the same time, from liquid cargo to dry cargo, project cargo and the need for MPV is growing because of its power of handling complex freight. The ability of the multipurpose vessels to carry different cargoes at the same time, enable them to navigate routes on which there are not sufficient volumes of dry bulk products and containers, respectively, to employ a dedicated dry bulk carrier or a dedicated container vessel at the same time. Therefore, Multipurpose vessel can be defined as a vessel which is not full container ship, dry bulk carrier, RO-RO ships, a reefer ship, or a heavy-lift ship, even if parts of its capability are overlapping to some level with these types and that makes the differentiation a bit harder [40]. A modern multipurpose cargo ship should have reasonable container capability as the containerizations of cargo are increasing in the future.

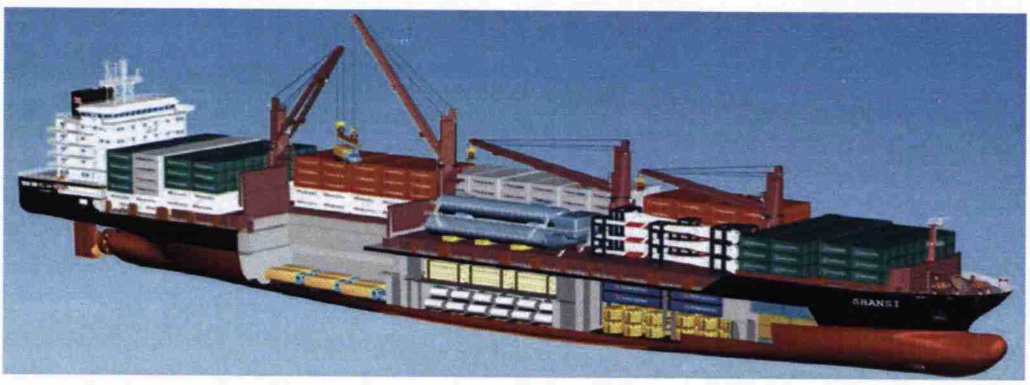


Figure 24 *An example of Multipurpose Vessel (source: CNCo)*

These vessels are often the result of unique designs and complex technical solutions that makes it possible to handle a wide range of cargoes. However, their varying operating conditions and complex design make them a challenge to design, build, maintain and operate [41]. Multipurpose vessel is suitable for both *deepsea* and *shortsea* shipping (the latter describes shipping at shorter distances in coastal areas; typical distances in Europe between 100 and 3000 nautical miles, with no clear separation between contract and liner shipping in this area) [42].

5.1 Unique Characteristics

There are some unique features and unique quality like high level of transport flexibility and versatility, own cargo handing crane in deep sea vessels makes it an individual type of vessel. Multipurpose vessel's cargo hold is used for different purpose of transporting different type of cargoes and its cargo handling activity is wide in nature which can be summarized as follows [42]:

- dry bulk commodities, (e.g. grains, ores, raw material)
- Neo-bulk[1] commodities, (e.g. steel, lumber, oranges, forest products)
- ISO containers (all sizes, standard/special types, for example, including reefer containers), heavy lift, large-volume cargoes, and
- Wheeled cargo units, optionally in partial stowage areas.

Therefore, a multipurpose vessel can be defined when it carries a certain type of cargo but at the same time it will change the definition by carrying different type of cargoes on later voyages. Advanced design and engineering solution is needed for future versatile cargo transportations.

[1] Neo-bulk commodities are generally handled like bulk commodities, except they move in small quantities per shipment.

Following section will deal with MPV cargo hold arrangement characteristics, cargo handling facility, MPV size trends and vessel's speed trends.

5.1.1 Cargo Hold Arrangements

One of the most uniqueness of MPV is the flexibility of cargo hold arrangements. Design of cargo holds for a multipurpose vessel depends on wide range of cargo features and conditions for handling, stowage, and treatment of cargoes. From special project cargo, steel coils and timber to bulk cargo, containers and dry goods, among others, the products being shipped place specific demands on the stowage and securing for safe sea transport [43].

A design factor of basic importance is the high level of cargo separation, that is, separation of limited quantities of different cargo types, port-to-port requirements, physical shape, and, perhaps incompatible characteristics and interrelations between cargoes. A further important reason for cargo hold separation, in the vertical direction in particular, is limited loading capacity by vertical stacking, in case of many break-bulk or unit loads. The project cargo ship has a large box-type cargo hold that can be subdivided into smaller holds using tweendecks and pontoons. On top of the hatch covers, there is a large open cargo space. The pontoons can be used to spread the load by allowing them to overhang the sides [42]. Separation in cargo holds both vertical and longitudinal direction is done to make sure the best operational service from the vessel. The vertical direction separation leads to an arrangement of at least one tweendeck, separating a lower hold of comparatively high net loading depth (for example, in the order of 3 to 6 m depending on ships size and overall depth) from a tweendeck (or more than one) of comparatively small net loading depth, for example, about 2.5 to 3.5 m. Smaller (shortsea) ships with a molded depth of about 6 m, do not have a tweendeck [42].

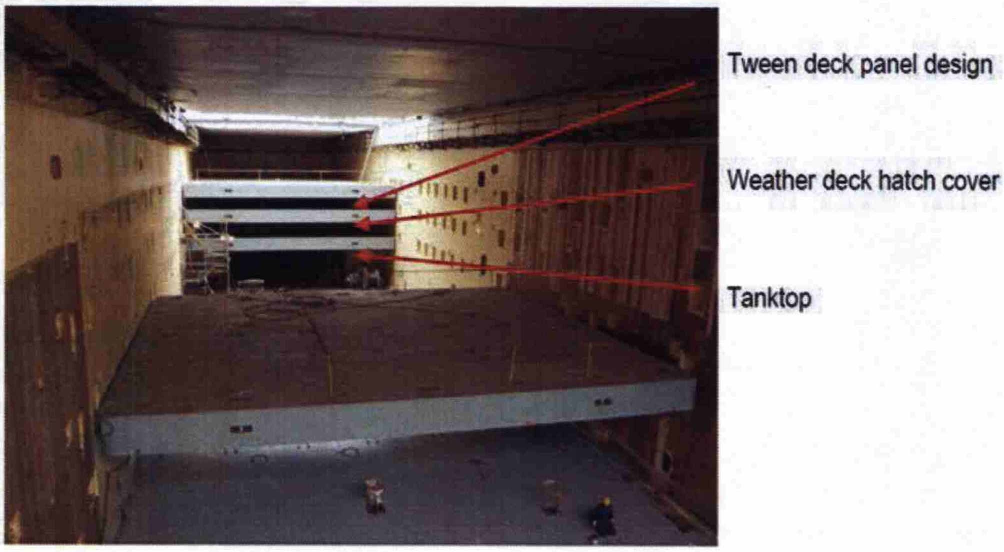


Figure 25 *Cargo loading flexibility - Multiple stowage positions of tween deck panels (Source: Germanischer Lloyd)*

Separation in longitudinal direction means subdivision into a number of cargo-holds. Cargo hold separation often is a compromise between a high cargo diversification, a reasonable single hold capacity, investment cost and the absolute dimensions of larger cargo units, such as containers, heavy-lift and large-volume cargo, watertight subdivision [42]. **Figure 26** shows the predesign and arrangements for the longitudinal bulkheads. The benefit of multipurpose vessel's cargo holds is the dynamic characteristics to facilitate carrying different cargo with different arrangements.

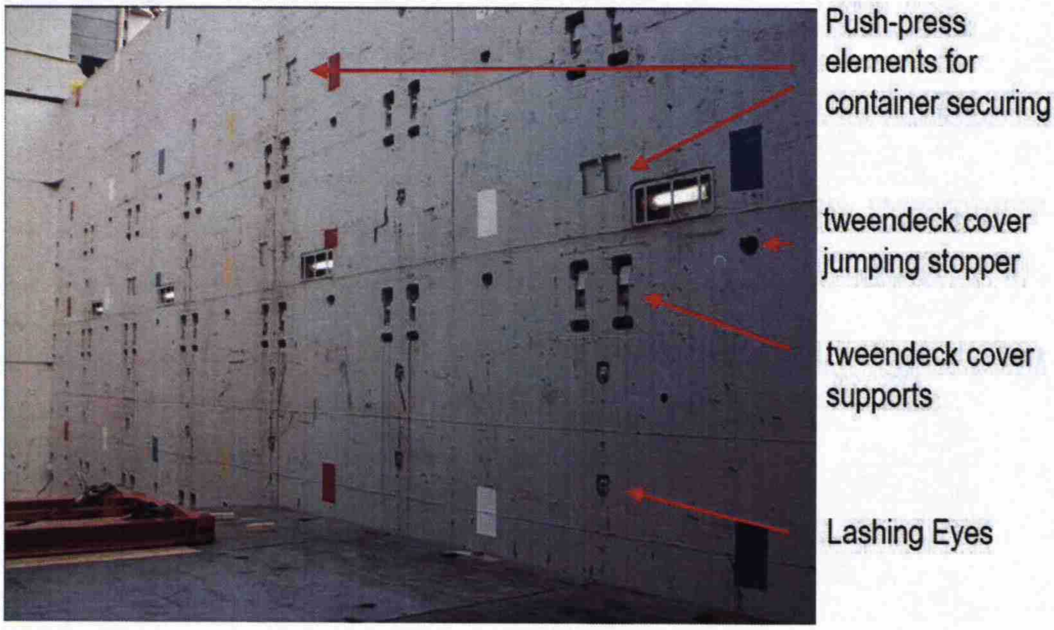


Figure 26 *Variable equipment on Longitudinal Bulkhead (source: Germanischer Lloyd)*

Efficient and flexible utilization of cargo space is the key to vessel profitability. Bulkheads improve the vessels cargo efficiency and flexibility by enabling segregation of different types of cargoes. Movable bulkheads can be flexibly moved with weather deck hatch covers and are hooked and locked by means of hydraulic systems. Some 'tweendeck hatch covers that can serve a dual function as bulkheads are manufactured by cargotec [44]. As the movable bulkhead can be positioned in different places in the cargo hold, the need for sealing is necessary to avoid mixing of the cargoes and water tightness in the cargo hold area. The Macgregor Bulkhead sealing gear provides an easy and safe solution for sealing the gap between the hull and the bulkhead **Figure 27**.

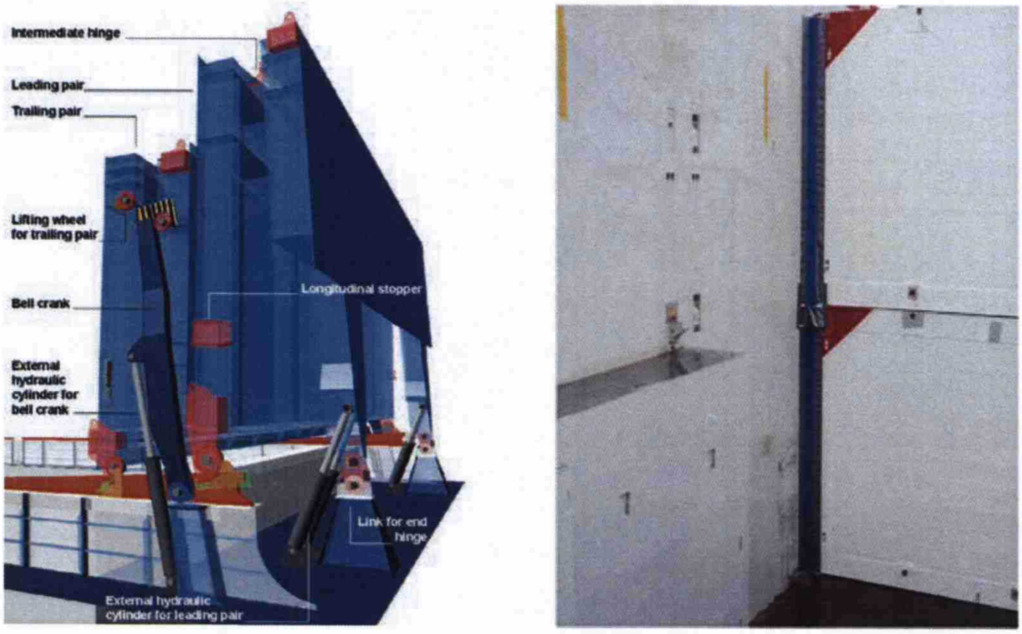


Figure 27 *Multi-folding hatch cover (Left) and Bulkhead Sealing System (right) (source: Cargotec)*

Beside the separation of cargo holds another important component is related to this matter is hatch cover. Importance of decision lies on whether to subdivide wide hatch openings in athwartships direction into multiple hatches or to provide an undivided single hatch. From the point of view of construction and investment for covers and moving devices, the latter option is preferable [44]. As hatch openings are becoming larger and larger, requirements for safe watertight closing, high carrying capacity hatch covers for deck cargo, fast, flexible opening and closing by safe, reliable, and uncomplicated mechanical means have become increasingly important. Fortunately, advanced technology, mechanically operated hatch cover systems are available, but a selection decision has to be made for a specific design purpose [42].

5.1.2 Cargo Handling Facilities

One of the important features for MPV is their cargo handling facilities e.g. cranes. Usually it is essential for deep sea route and to the port where suitable cargo handling equipment crane are unavailable and often it comes with the owner's requirements. Even in some ports cannot provide enough draught thus requires a feeder vessel to transport the cargoes and need onboard cargo handling facilities to transfer the cargoes. Optimum design is needed to make the crane arrangement in such a way to minimize the time and costs for handling the cargoes. Beside the facilities presents in any port, operation of both onboard and port cargo handling gear is also used now in recent times to increase the overall efficiency [42].

Positioning the crane onboard of the vessel demands extensive engineering and predesign analysis to ensure the safety of operation. Feasibility studies are required to ensure the hatch cover and 'tweendeck hatch cover operation at any loading condition along with crane operation [45]. Fixed slewing cranes are located at the ship's centerline which gives symmetrical cargo handling possibilities in both athwartships directions (**Figure 28**). But this arrangement resulted high amounts of rotating load motions, instead of straight translator and results in direct horizontal load motions [42]. Thus, the centerline arrangement does not reflect to be an optimum one. Rather the crane positioned non-symmetrically on the side edge of the deck, usually on the port side and connected to the longitudinal girder found to be more flexible and optimum. This also offers freedom for hatch arrangements e.g. folding or sliding hatch cover. These arrangements are applied to the ships with beams up to about 22 m as the maximum crane outreach is limited to 28m by regulation [42].

Figure 28 *Cranes positions at centerline of the ship (Left) and crane at side (right) (Source: Cargotec)*

Crane design trends for multipurpose vessel are important to be noticed. Load carrying capacities for the cranes are now increasing due to advance research and development. There are number of different type of cranes available and each of them has different working performance and purpose. Usually GLE/GL type cranes are used for cargo handling in container ships, bulk carriers and general cargo ships and for handling heavy and multipurpose cargoes, GLH/ GLHE type cranes are used [46]. Variable frequency drive (VFD) or electrically driven cranes are going to be increasingly popular because of their lower energy consumption, precise and faster crane operation. Positive efficiency resulted out from the faster and more accurate grab positioning which essentially helps to reduce the time spent in ports. About 30 to 35 percent reduction in power consumption can be achieved along with lower carbon footprint which is beneficial to ship's environmental rating [47].

In the future the crane design will experience a massive change due to the innovation of new materials and technology. Air cushion or magnetic levitation technologies will come forward and automatic monitoring system for wear and tear and ordering the maintenance, repairing task could be done in future cargo handling systems.

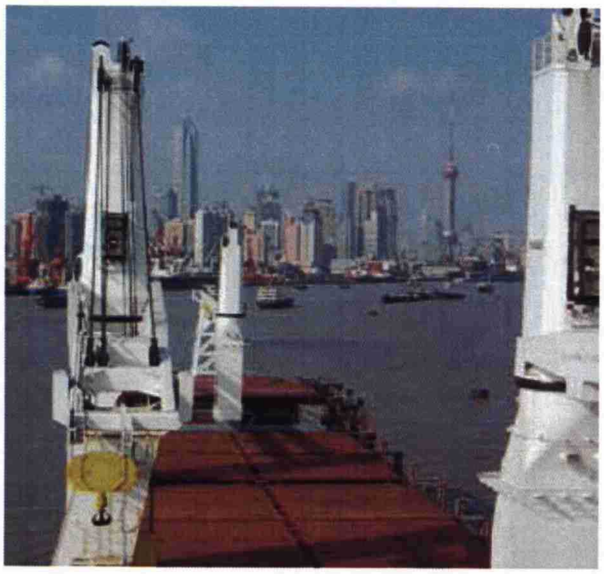


Figure 29 *GLH/GLHE cranes (source: Cargotec)*

Nano-fibre technology is advancing thus can replace the steel wiring of the crane and also save the lightweight of the vessel which is at the moment very expensive [48]. Cargo rail crane will be presented onboard of bigger multipurpose vessels to offer more flexibility in cargo handling.

5.1.3 Size/capacity Trends

In terms of MPV supply, the market is on a solid foundation. It has been seen that the deadweight capacities for MPVs are in range of 100 tonne DWT up to about 30 000 tonne DWT, and, in a very small number of exceptional cases, up to more than 40 000 tonne DWT. The dominating group is from 15 000 to 20 000 tonne DWT [42]. It has been found as of 1 January 2012, the total fleet numbers of MPVs (globally) are 3096 vessels totaling almost 28.0 million DWT. In 2011, the MPV fleet grew by 3.1% [5]. Germany, Netherlands and China combined are in control of half of the multipurpose vessels in service and ordered (**Figure 30**).

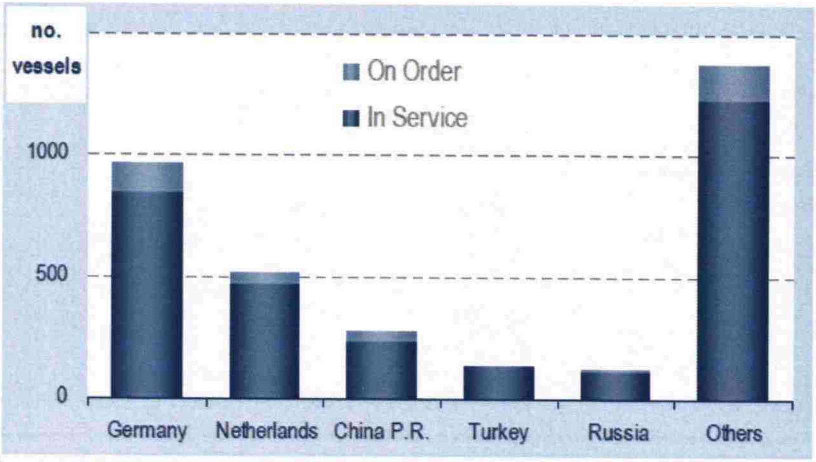


Figure 30 *Top 5 Owner countries of MPVs (source: Germanischer Lloyd)*

Drewry maritime research group have analyzed the MPV fleet by dividing the fleet into six deadweight sectors as shown in **Table 3** MPV Fleet by size range as of 1 January 2012 (source: Drewry Maritime Research, derived from Clarksons) below, with the main characteristics of each vessel size category [8].

Table 3 *MPV Fleet by size range as of 1 January 2012 (source: Drewry Maritime Research, derived from Clarksons)*

	No of Vessels	Total DWT	Average DWT	Average Age	Total TEU capacity	Total Grain Capacity	Avg SWL[2] (Tonne)
<5,000	1,073	4,125,762	3,845	16	213,384	5,168,755	40
5-10,000	1,143	8,191,089	7,166	15	432,488	9,052,821	64
10-14,999	396	4,846,451	12,239	10	251,599	5,344,917	116
15-19,999	222	3,909,175	17,609	15	167,141	4,598,917	103
20-24,999	139	3,054,777	21,977	17	134,165	3,984,235	78
>25,000	123	3,888,097	31,611	8	182,679	4,051,394	123
Total	**3,096**	**28,015,351**	**8,828**	**16**	**1,381,456**	**32,201,040**	**69**

[2] SWL = Safe Working Load , is the load that a piece of Lifting Equipment can safely lift, suspend, or lower without fear of breaking (Source: Wikipedia)

It can be seen that the youngest vessels are going to be larger in size because of more efficient in operation. Energy Efficiency Design Index (EEDI) that came into force from 1 January 2013 and makes change in design trends and increase environmental pollution control awareness. In short EEDI is the measure of CO_2 emission characteristics of a ship's propulsion energy usage only based on its design. **Figure 31** shows the amount of CO_2 emission from different size of MPVs. Total number of ships that is taken into consideration are 12290 and with stat code A31A2GX. The red-line is the IMO reference line and it is found that about 46% of these vessels are above that reference line [49].

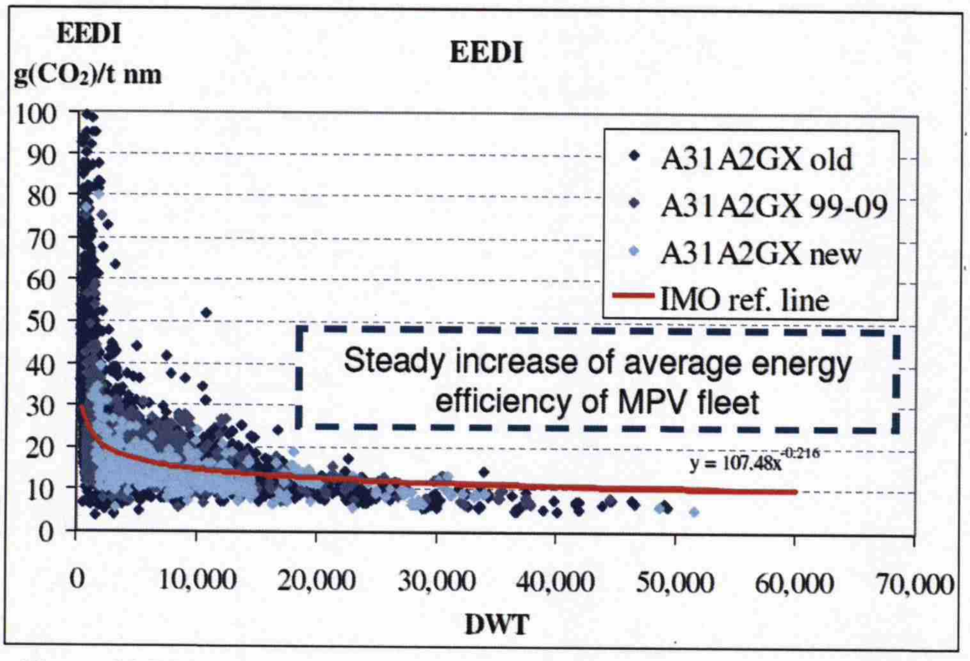


***Figure 31** EEDI overview with respect to DWT (source: Germanischer Lloyd)*

Because of new environmental regulation, from **Figure 32** it is visible that vessel size is increasing to obtain better EEDI value. The vessels on ordered to be delivered until 2014 is well following the new rules and emits less than 10 g (CO_2)/t nm. Average energy efficient and ship size of MPV fleet increases, while average speed stays constant. It is found that for the future choice for larger vessels (15,000 to 20,000 DWT) gives the result of good energy efficient characteristics for the ship [49].

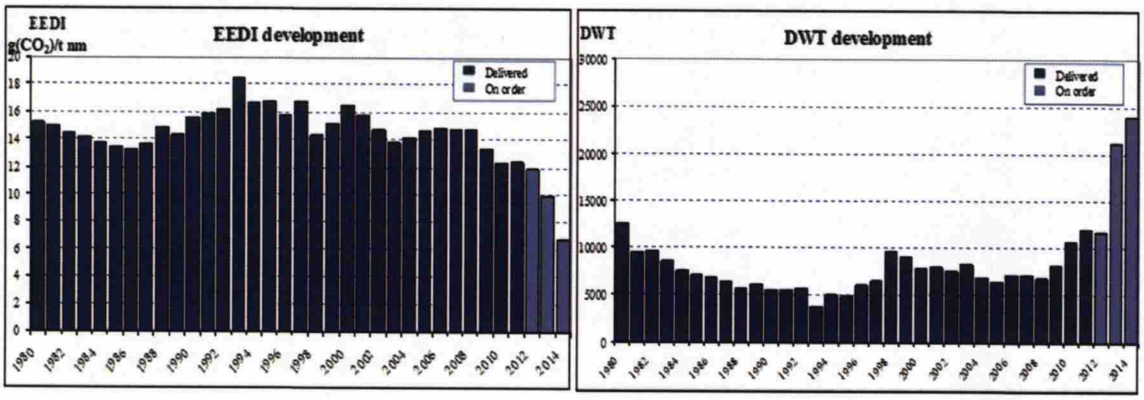


Figure 32 *EEDI and DWT development from 1980 to 2014 (source: Germanischer Lloyd)*

5.1.4 Speed Trends

Speed is one the important factor for the ship to be optimized for the new rules and regulations. Typical speeds of multipurpose cargo ships defined under certain given conditions, for example, trial conditions and at full or partial load or design condition, depend on the wide range of size and operating conditions of this type. [42]. **Figure 33** shows the speed and power-capacity development for the multipurpose vessels. It is seen that medium to larger ships for contract operation have a speed range of 14 to 16 knots, which has not changed much during recent decades [42]. Medium to larger ships in the liner services have moderate speeds, but still higher than those for contract operation, mostly in the range of 16 to 18 knots. Smaller ships for shortsea operation naturally are running slower, often at speed ranges of 12 to 15 knots, but sometimes even as low as 10 to 12 knots [42]. The design speed for MPVs larger than 10,000 DWT and /or 1000 TEU sail almost all at least 19 knots design speed [42].

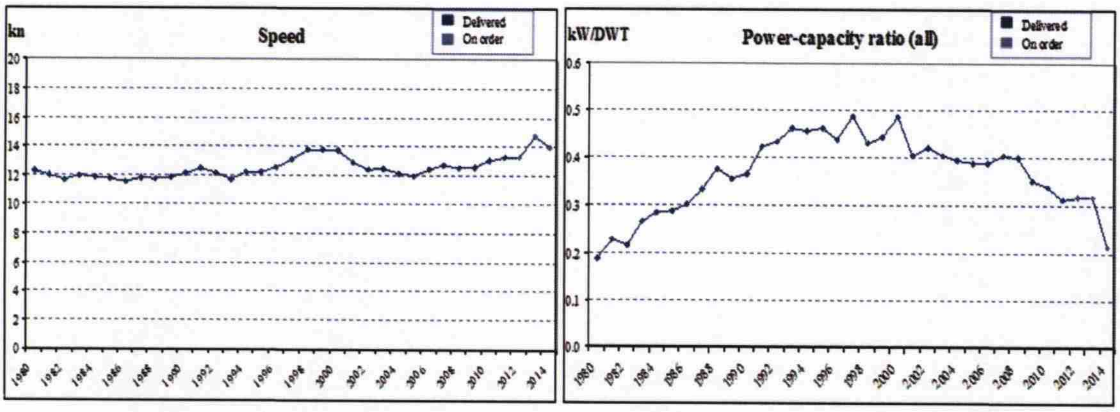


Figure 33 *Speed and power-capacity development for MPVs (source: Germanischer Lloyd)*

The figure above also indicates that more energy efficient ships are going to enter into the market without minimizing the performance and capacity. The operational speed of 25 MPVs in the strait of Taiwan was measured; the maximum was about 17 knots and the average about 12 knots [49]. According to Germanischer Lloyd choice 17 to 18 knots is good to ensure competitive and energy efficient MPVs [49].

5.2 Multipurpose shipping market

This sub-section will focus on the trade, fleet development, market condition for the multipurpose shipping from the global point of view and their probable changes in the near future.

5.2.1 MPV Trade

Multipurpose vessel's trade is involved with dry cargo market which has different segments starting with the division of bulk and non-bulk traffic. As it is shown in **Figure 34**, within these divisions there is further subdivision: major bulks, minor bulks and neo bulks on the one hand and unitized and non-unitized on the other. This figure also shows the competitive vessel type in the respective cargo segments in 2011.

MPV fleet is involved with market share both in container and break-bulk dry cargo segment. But the market share of the container market is shrinking because of increasing cellular ships are moving into that fleet. Major bulk share (iron ore, coal, grain in bulk) carried on MPVs is expected to remain on the similar levels to the container share. Minor bulk that is steel and forest products and general break-bulk cargos are the significant to this sector. Globally steel production is expected to increase at a slower rate mainly because of slowdown in the global and Chinese economies [5]. On the other hand, pattern of demand for forest products is changing. China is still the world's largest importer of wood pulp and logs while second largest import of softwood timber [5]. Bio-products developments are increasing which will eventually lower the cargo volume in the future.

Dry cargo market segments						2011 trade: million tonnes	Primary cargo markets for multipurpose vessels	Competing vessel types
Dry cargo	Bulk cargo	Major bulk cargo	Major bulk cargo	Major bulk cargo	Iron ore, coal, grain	2,188	MPV share of major bulks	Bulk carriers
		Minor bulk cargo	Other minor bulk cargo	Other minor bulk cargo	Phosrock, bauxite, other	983	MPV share of other minor bulks	Handy bulk carriers
			Neo/agri-bulk cargo	Neo/agri-bulk cargo	Iron & steel, forest products, fertilisers, sugar, rice		MPV share of new-agribulks	Handy bulk carriers, Ro-Ro ships
	Non-bulk cargo	General cargo	Unitised general cargo	Containerised general cargo	General cargo in containers	1,458	MPV share of containerised general cargo	Containerships, Ro-Ro ships, Con-bulkers
				Other unitised general cargo	General cargo in trailers	421	Other unitised general cargo	Ro-Ro ships, ferries
			Non-unitised general cargo	Specialised general cargo	Reefer, vehicles	62	Specialised general cargo	Reefer ships, car carriers Ro-Ro ships
				Non-specialised breakbulk general cargo	All types of non-unitised general cargo & project cargo	518	Non-specialised breakbulk general cargo	Ro-Ro ships, heavy lift ships

***Figure 34** Multipurpose fleet primary cargo market segments and competitive vessel types (source: Drewry*

MPV market share have fierce competition with containership sector and Drewry have seen positive growth for container ship market. Therefore, the market share for MPV will slowly decrease in future as forecasted in **Figure 35**.

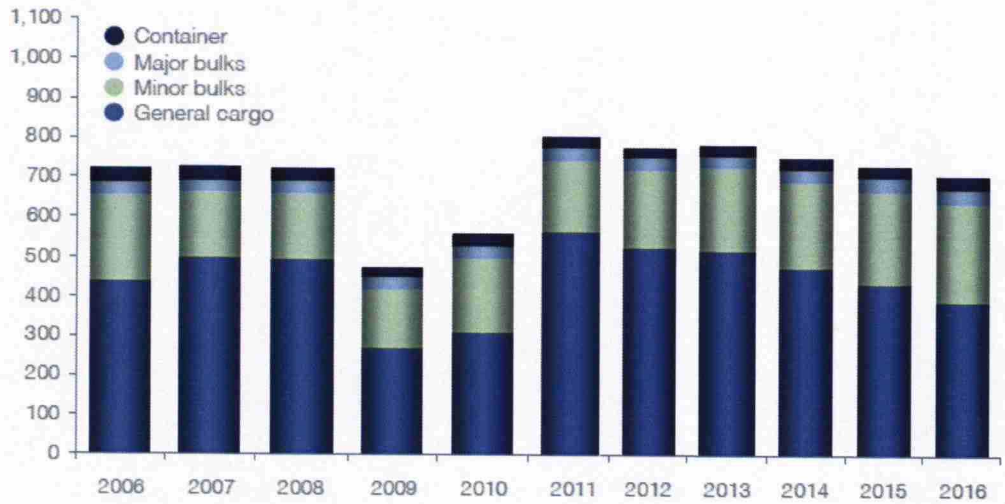


Figure 35 *Future growths in multipurpose share of dry cargo market (million tonnes)*
(Source: Drewry Maritime Research)

However, Drewry Maritime Research has also suggested that the steadily rising demand for minor bulks, plus the low growth in the Handy fleet, could offer market growth for MPV and MPV volumes for this sector are expected to grow at around 7% a year up to 2017 [5].

5.2.2 MPV Fleet development

Multipurpose vessel fleets are growing steadily. Unlike the position of the fleet few years ago where there was about 19% drop in demand for MPVs in 2009 [8]. It has been forecasted by Drewry Maritime Research group that MPV fleet will grow at about 1.9% per year till 2016. The current orderbook is equivalent to 17% (in deadweight terms) of the operational fleet; with the larger vessel sizes are still popular for new tonnage [5], which can be seen in **Figure 36**.

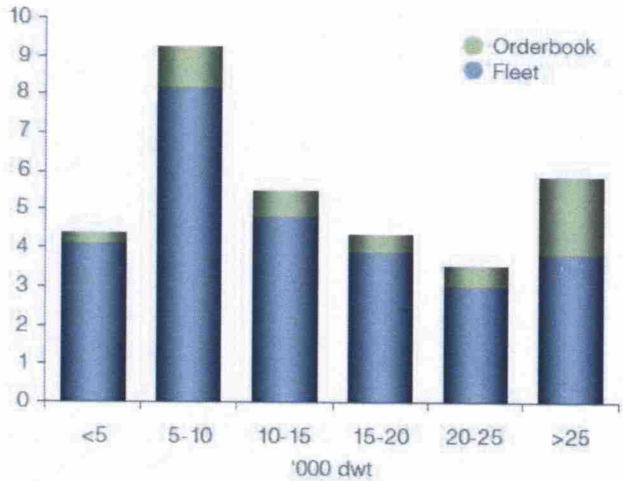


Figure 36 *MPV fleet and order book as of 1 January 2012 (million dwt)*
(Source: Drewry Maritime Research)

Multipurpose segment is also facing increased demolition activities. In 2011, about 2 million dwt of multipurpose tonnage was sent for demolition which was about 33% higher than the year of 2010 [5]. Vessels with 15-20,000 dwt and 20-25,000 dwt segments have experienced highest demolition (**Figure 37**). This demolition activity was supported by the rise in scrap prices for multipurpose tonnage. In 2010 the price was $380/ldt which rises to $480/ldt in 2011 due to overall increase in steel price in global market [5]. Even though, MPV segment facing difficulties, Drewry expects the long term prospects for MPV is promising.

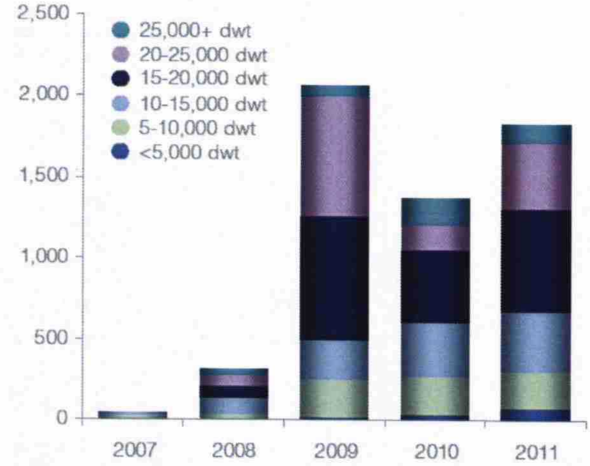


Figure 37 *MPV demolition by segment ('000 dwt) (source: Drewry Maritime Research)*

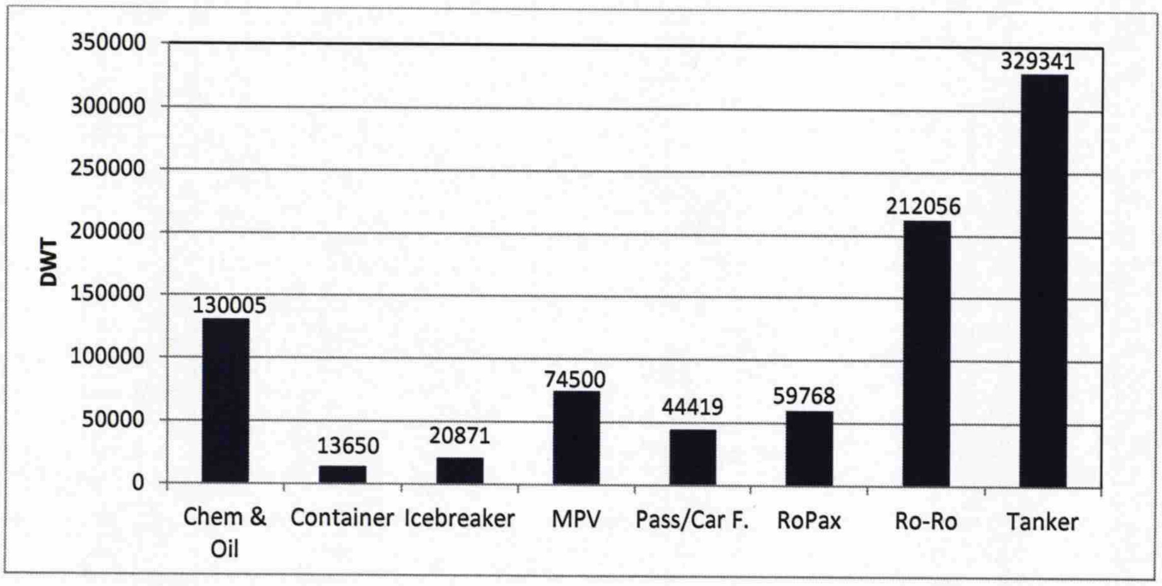


Figure 38 *Major Finnish flagged vessel type (source: Clarksons)*

There are about 14 multipurpose vessels with Finnish flag totaling 74,500 DWT (**Figure 38**). Most young vessel is from Langh Ship Oy, M/S Aila and M/S Linda with 6 years age each. Excluding this two vessels, the average age of the fleet is 21 years with the most aged vessel of 36 years. So, it can understood that most of the vessels will be scraped or sold out or operate outside the ECA due to new environmental legislation thus creating need for newer vessel.

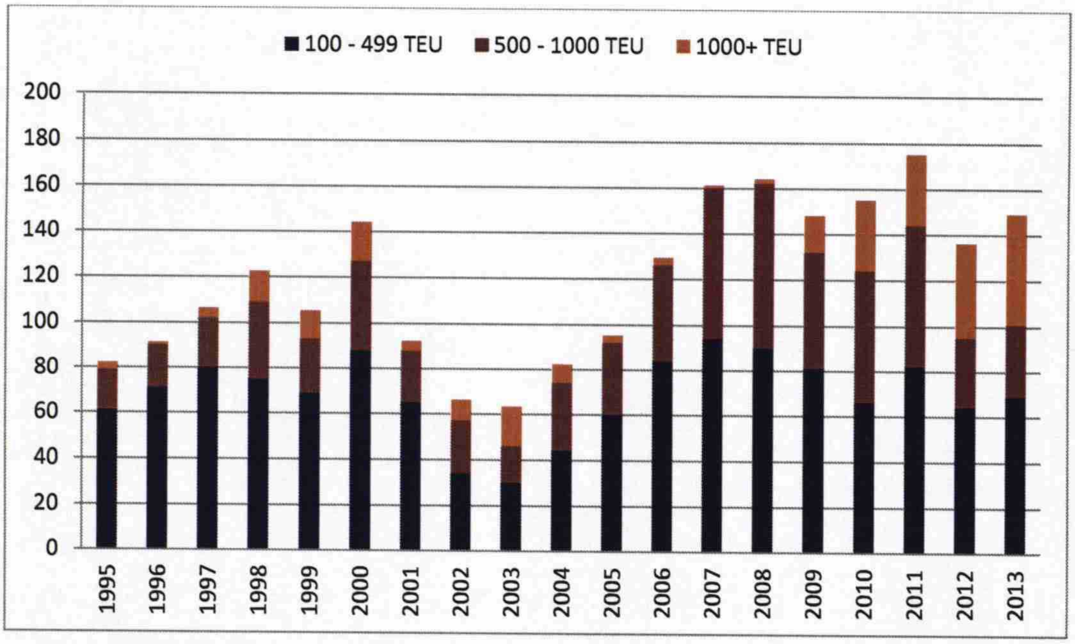


***Figure 39** Number of MPV fleet delivery per year based on TEU group (Data source: Clarksons)*

Figure 39 shows the historical development of MPV fleet based on TEU capacity and it can be seen that recently MPV with 1000+ TEU capacities is in steadily increasing demand. Demands for 1,000+ TEU MPVs are expected to grow by an average of 7% to 8% per annum between 2016 and 2025 (Clarksons). Drewry Maritime Research have made an expected development of the MPV fleet including heavy-lift vessels upto 2016 based on current order book schedule, projected slippage and projected demolition numbers (**Figure 40**). About 40% of MPV orders which was scheduled to be delivered in 2011 have slipped into 2012 and possibly beyond. As the owners are not showing interests of return to ordering newbuildings at the rate seen in 2007 and 2008, this slippage is expected to fall further. On the other side, demolition level expected to rise further. This combination of newbuildings-deliveries and demolitions makes the fleet growth at an average annual rate of 1.9% until 2016 [5].

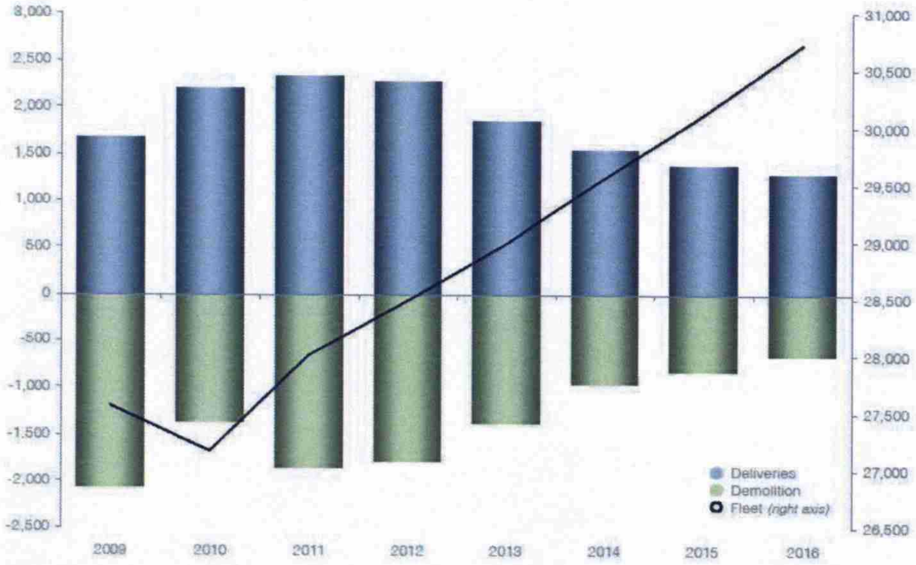


Figure 40 *Suggested MPV fleet development by DWT upto 2016 ('000 dwt) (Source: Drewry Maritime Research)*

Beside the TEU capacity, according to Germanischer Lloyd 80% of their classed MPVs are ice classed and almost half of the total MPV fleet above 10,000 dwt have ice class 1A (E3). Notations E1 to E4 correspond to ice classes IC to IA "Super" of the Finnish/Swedish Ice Class Rules [49].

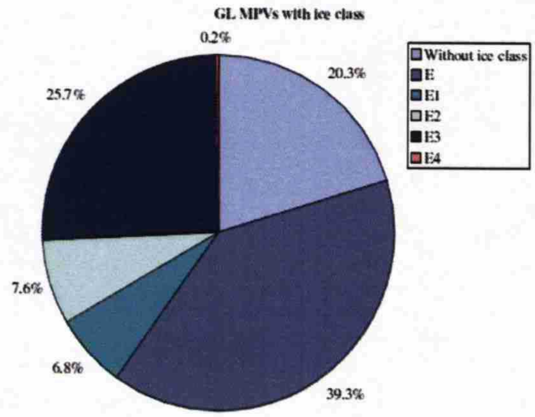


Figure 41 *GL MPVs with ice class (source: Germanischer Lloyd)*

5.2.3 MPV Market and Economy

Market trends within MPV sector are mostly linked with both the dry bulk and container sectors, therefore, the threats and opportunities for these markets also interconnected to each other. Based on container carrying capacity, MPV is divided into following groups by Drewry Maritime Research:

Container-oriented	DWT/TEU < 20
Container-friendly	DWT/TEU >= 20 < 35
Container-capable	DWT/TEU >= 35<45
Container-incapable	DWT/TEU >=45

Container oriented MPV takes the market lead from developments in time charter rates for cellular containerships. Stability in the container oriented MPV was seen due to demand in the break-bulk sector. Time charter rates are also affected by its competitive market conditions, especially handy bulk carrier and container ships. Based on the time charter rate from 2001 to 2011 for different capacity (Deadweight- DWT) of MPVs, forecast is made in excel using SQL data forecasting method based on the statistical value of past years (**Figure 42**). The data is expressed on average annual period rates [5].

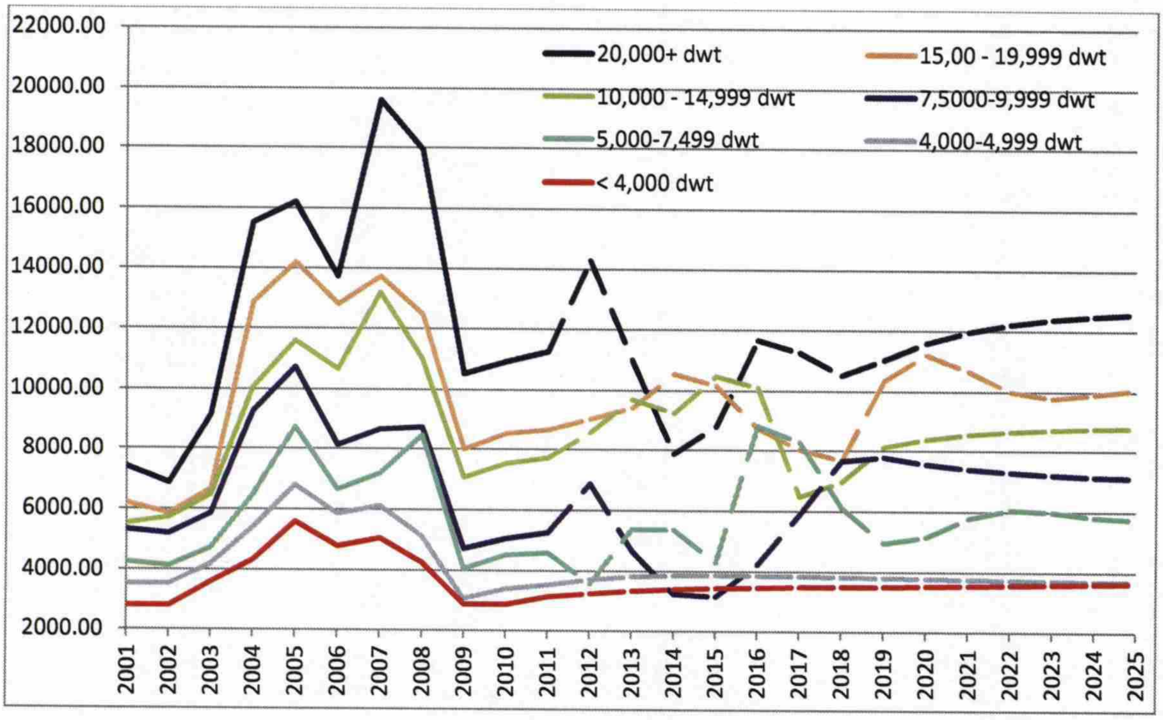


Figure 42 *Suggested development of time charter rates in Future ($/day)*
(Source: Modified from Drewry)

It can be seen that the smaller size of the ship suffers less during drop of the demand for transporting cargo. But from 2020 to 2025 the fluctuations in every section is expected to be on a steady growth. On the other hand, **Figure 43** shows the variation of average Baltic Exchange Freight Index and Containers Freight Index Clarkson from 1990 to 2012 and forecasted in excel upto the year 2025. These indexes also give the indication of the economic growth (if the index is rising) and contraction (if the index is falling). Based on the forecast it is expected to have the growth of shipping economy gradually growing in the future. But as this forecast is done on the basis of statistics of previous years only, so the future scenario might be changed as shipping market is affected by many other unknown factors as well.

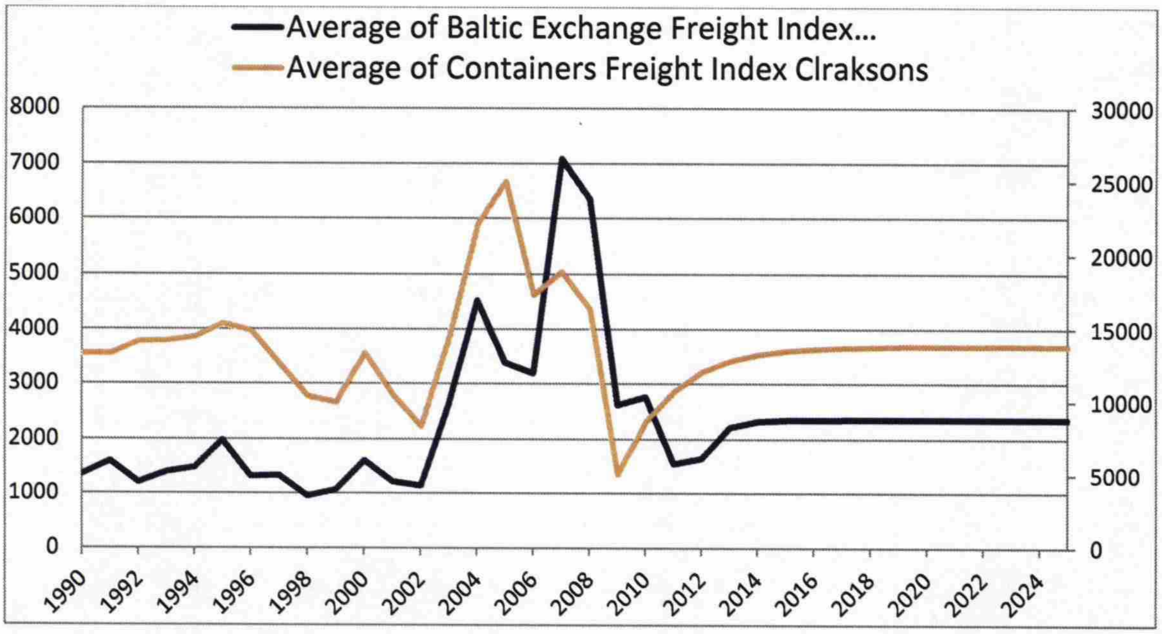


Figure 43 *Index rate for Baltic exchange Freight index and containers Freight index Clarkson*

Shipping costs are usually defined with three subdivisions which are capital costs, operating costs and voyage costs. Among these, operating cost is the important issue for the owners as it is the deterministic factor for the profit. Some additional factors like insurance cover for kidnap and ransom making the overall costs to rise by 2-3% in the multipurpose sector [5]. From **Figure 44**, it can be seen that manning costs is the largest item under the operating cost for the vessel. Multipurpose vessels are manned at the same levels as bulk carriers and container vessels which are from18 to 20 sea-personal [5].

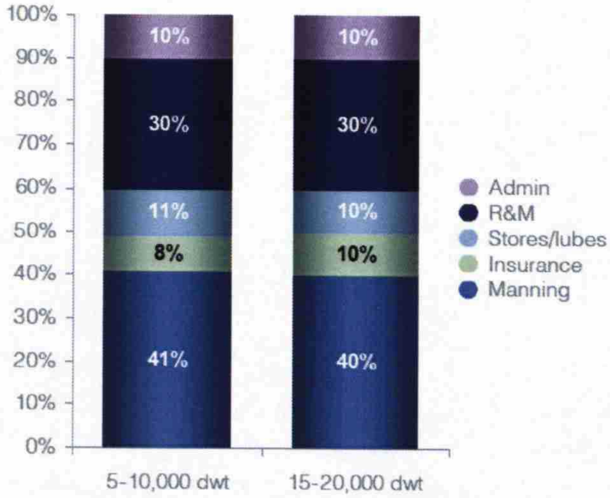


Figure 44 *Daily operating costs in 2011, general cargo vessels (source: Drewry Maritime Research)*

With the continual increment of cost for manning will move to design a vessel with more automation in nature and less dependency on human to save money for the owner. Other partition like insurance have become more interlinked with the shipping business and for 2011, the best owners experienced premiums being cut. Additionally, piracy activity by the Somali pirates still dominating and raises the amount of ransom from average of $3.4 million in 2009 to $5.4 million in 2010, making piracy as an unavoidable issue considering the insurance settlement [5].

5.2.4 Competitive Threat

Market analysis of container ship and bulk carrier is necessary to forecast about the future fate of MPV as these two segments are competing for the cargo share. The market of MPVs is in competition with the container market and dry bulk sector. Ongoing shift towards containerized trade leads to a steady melt down on the MPV sector [49]. Despite the overall economic crisis, growth for container trade is significant. Drewry Maritime Research have seen that a considerable number of container ships to be laid up in recent time and independent owner of this fleet have to prepare for considerably poorer employment prospect. This sector is also suffering as a result of slow global trade, over capacity of vessels and lower freight rates [50]. However, global container transport is expected to continue to grow in the future. **Figure 45** shows that the rate of supply is larger than the demand rate for container ships making the overflow capacity in the market [7]. The Largest threat lies within the continued containerization. The containerization trends are the outcome of improved port container infrastructures. So, a gradual decline of non-containerized cargo volume should be considered as a major threat to the MPV segment [49].

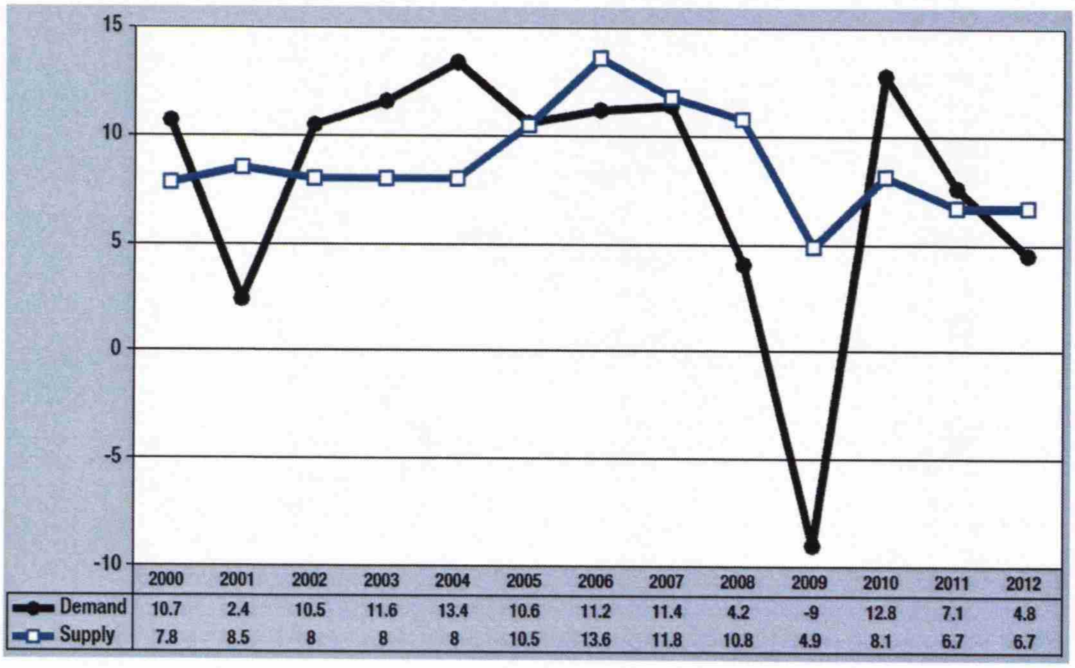


Figure 45 *Growth of supply and demand in container shipping (annual growth rate) –Clarksons*

On the other hand, dry bulk market is affected because of EU financial crisis which essentially slowing down the steel production in China. Demand for dry bulk which was around 4% in 2012 is expected not to exceed 5% until after 2013 [5]. Because of the excessive supply of bulk carrier fleet in the market, the situation for this fleet could get worse. In recent years, supply shortage of handy bulkers leads to an opportunities for MPV's on the minor bulk sector [49]. The major bulk cargoes includes coal, iron ore and grains and minor bulk commodities include fertilizer, wood products, cement, metal ores etc [51].

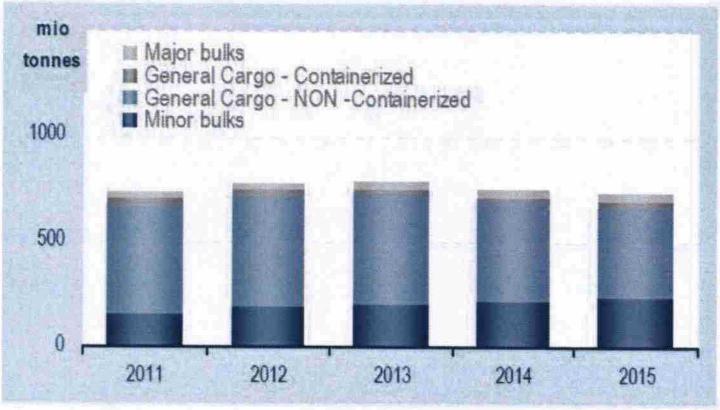


***Figure 46** Seaborne trade relevant to MPV market share (source: Germanischer Lloyd)*

Minor bulks as well as non-containerized general cargo (steel coils, construction commodities and project cargo) are very important to the MPV market. Major bulk also plays important role on a minor scale. **Figure 46** indicates the decrease in market share for MPV in the near future. NON-Containerized General Cargo volume is expected to decrease while Minor bulk can provide greater opportunity for MPV sector to survive. Increasing rate of containerization posing threat to the MPV sector, therefore, container-oriented MPV will be more beneficial for the shipowners.

6 Future Machinery Concept for Multipurpose vessel on the Baltic Sea

This chapter will discuss about the alternative future machinery concepts that will pass all the future environmental legislations and still cost efficient solution for the shipowners. Five different machinery concepts are taken for the evaluation and operational profile of an existing vessel M/S Aila of Langh Ship Oy is taken as reference. The task is done using ShipMac program developed by Wärtsilä Finland Oy.

6.1 Case Vessel and Method

M/S Aila is Germanischer Lloyd classed multipurpose vessel with Ice class 1A super under Finnish flag which was built in 2007 (**Figure 47**).

Figure 47 *Multipurpose vessel M/S Aila (source: Langh ship)*

Table 4 *Principal dimensions of M/S Aila*

Length	141.20 m
Breadth over all	21.55 m
Draught	8.60 m
Service speed	17.7 knots
Container capacity	907 TEU
Deadweight (Tonne)	11,500

Eight different operational mode of the vessel was tracked for two weeks and then converted to an annual operation period. Electrical load for each of the operation condition and propulsion power demand for different speed was estimated for both open water and ice operation. **Figure 48** shows the operational profile of M/S Aila and **Figure 49** shows the power demand for different speed in open water condition.

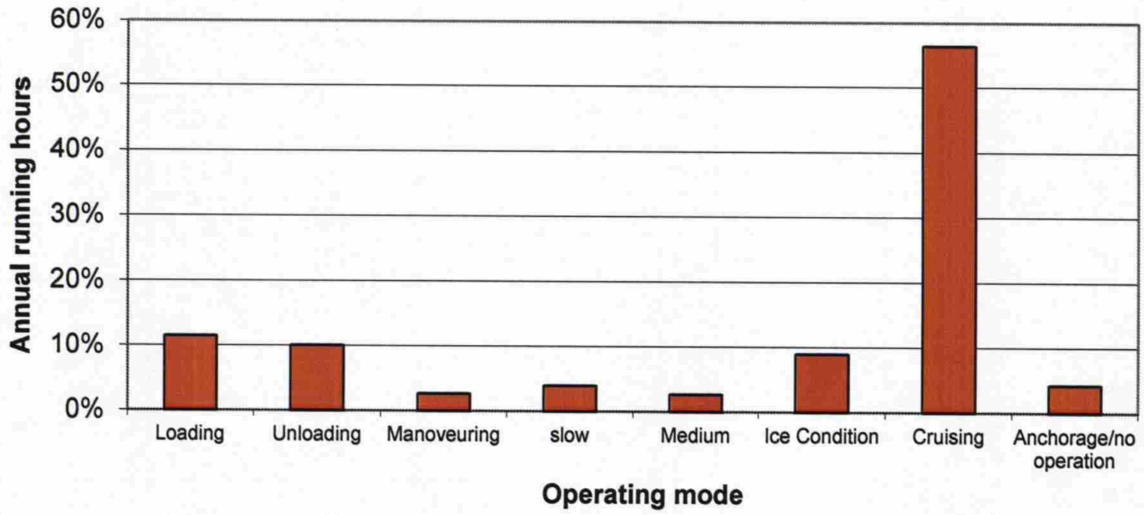


***Figure 48** Annual running hours at different operating mode - M/S Aila*

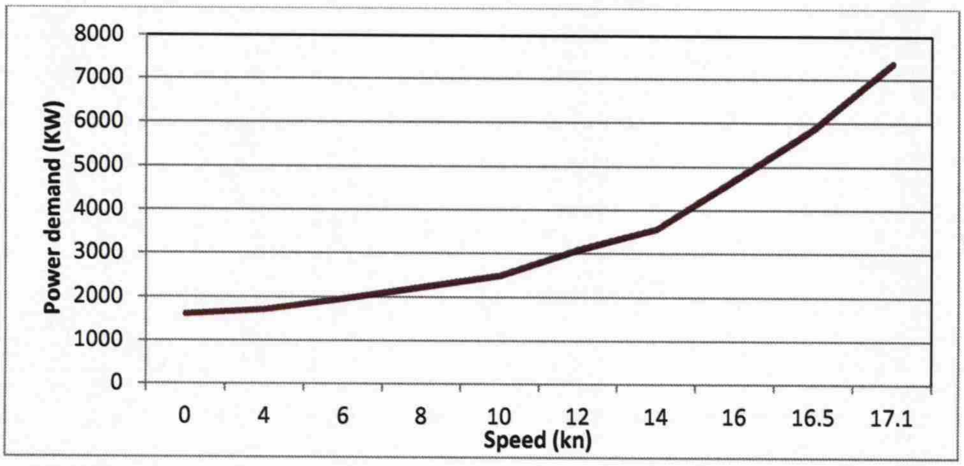


***Figure 49** Power demand curve for open water condition -M/S Aila*

6.2 Machinery and propulsion configuration

Single screw, Twin Screw, CRP POD and Double acting arrangement, four different machinery concepts were evaluated with respect to the reference vessel which has Single screw propulsion with MGO as main fuel and having scrubber system to meet future IMO emission control requirements. All these four alternative concepts have LNG as main fuel and MGO as auxiliary fuel for the electrical load. Propulsion power demand for each of the cases both in open water and ice condition was calculated based on data of a number of existing vessels with respective machinery arrangements as shown in **Table 5**. Detail of the propulsion power demand for all the cases is give in the Appendix.

***Table 5** Propulsion power estimation assumption for different machinery concepts*

Cases	Propulsion system	Main Fuel	Power Demand in Open Water	Power Demand in Ice Condition
Reference (Case 5)	Single Screw	MGO	Given in Operational profile	Assuming for same Power , speed will be 4 knot less compare to open water
Case 4	Double Acting POD	LNG	Assuming + 4.5% than Ref.	Assuming - 30% than ref.
Case 3	CRP POD	LNG	Assuming - 7% than Ref.	Assuming for same Power , speed will be 4 knot less compare to open water
Case 2	Twin Screw – Twin Skeg	LNG	Assuming - 6% than Ref.	Assuming for same Power , speed will be 4 knot less compare to open water
Case 1	Single Screw -	LNG	Same as Ref.	Assuming for same Power , speed will be 4 knot less compare to open water

Single Screw Machinery Concept

This machinery concept consists of 2-stroke Dual fuel Wärtsilä engine, which run on Liquid Natural Gas (LNG) and Marine Gas Oil (MGO). A controllable –pitch (CP) propeller is driven by one (1) Wärtsilä 7RT-flex50DF, 8400 KW dual fuel engine. This engine is IMO Tier III compliant and not released for sell yet by Wärtsilä. But, the preliminary general technical data has proven that Wärtsilä 2-stroke dual fuel engine will be best feasible engine solution for the future. All electrical power is generated by three (3) Wärtsilä 6L20DF medium speed dual fuel generator sets, with total installed power of 2628 KW. The electrical power is used to power both the bow thruster as well as the entire hotel load. The total installed power is 11,568 KW and total propulsion power is 8400 KW (CP propeller). The losses of electrical propulsion and generators (about 8%) are taken into account in the dimensioning of the generator sets.

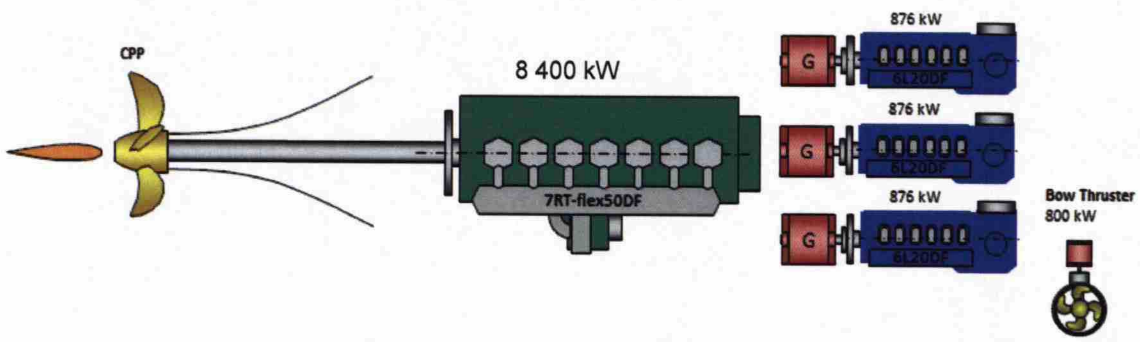


Figure 50 *Single-screw machinery configurations for the multipurpose vessel*

Twin Screw Machinery concept

This machinery concept consists two (2) controllable –pitch (CP) propellers which are driven by two (2) Wärtsilä 9L34DF, 4050 KW (each) medium speed dual fuel engine. All electrical power is generated by two (2) Wärtsilä 6L20DF medium speed dual fuel generator sets, with total installed power of 1752 KW. The electrical power is used to power both the bow thruster as well as the entire hotel load. The total installed power is 9850 KW and total propulsion power is 8400 KW (CP propeller). The losses of electrical propulsion and generators (about 8%) are taken into account in the dimensioning of the generator sets.

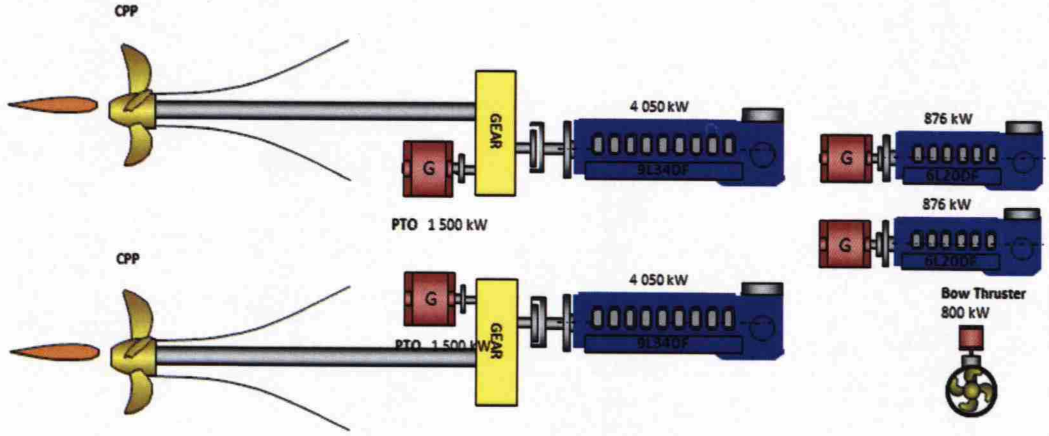


Figure 51 *Twin-screw machinery configurations for the multipurpose vessel*

CRP POD Machinery Concept

The CRP (contra-rotating propeller) – Azipod machinery concept consist of 2.3 MW Pod with 5500 KW CP propeller. CP propeller is driven by one (1) 4-stroke medium speed Wärtsilä 6L50DF (5700 KW) engine. All electrical power is generated with one (1) Wärtsilä 6L34DF (2700 KW) and one (1) Wärtsilä 6L20DF (876 KW) medium speed dual fuel generator sets. Total installed power is 9,276 KW and total propulsion power is 8500 KW (Pod Power + CP propeller). The arrangement is shown in **Figure 52** below:

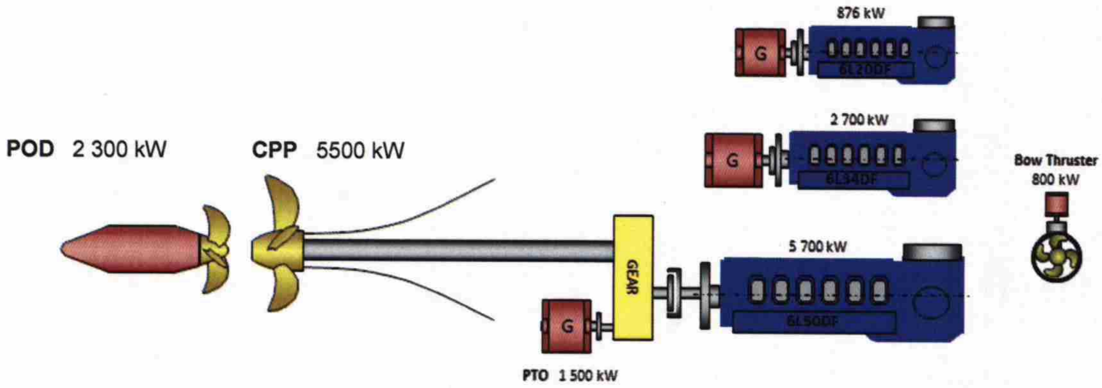


***Figure 52** CRP-POD machinery arrangements for the multipurpose vessel*

Double Acting Machinery Concept

This machinery concept consists of one (1) double acting pod (8400 KW) which is electrically driven. All electrical power is generated with one (1) Wärtsilä 9L34DF (4050 KW), two (2) Wärtsilä 6L34DF (2700 KW) and one (1) Wärtsilä 6L20DF (876 KW) medium speed dual fuel generator sets. Total installed engine power of the generating sets is 10,326 KW and total propulsion power is 8400 KW. The machinery arrangement of this concept is shown below:

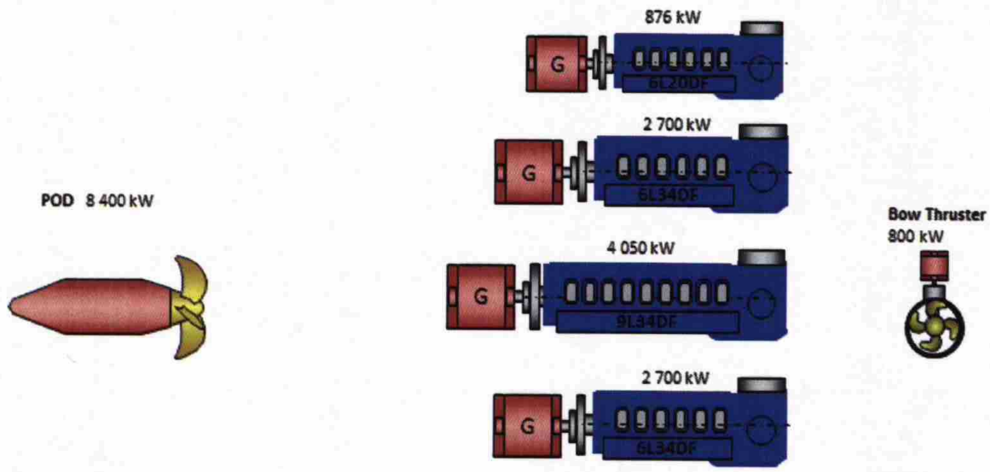


***Figure 53** Double acting POD machinery arrangements for the multipurpose vessel*

Single Screw (MGO) Machinery Concept (Reference case)

This machinery concept consists of a controllable –pitch (CP) propeller which is driven by one (1) Wärtsilä 7L46F, 8400 KW, 4-stroke diesel engine. All electrical power is generated by three (3) Caterpillar 3508B diesel generating sets of powering 630 KW each. The electrical power is used to power both the bow thruster as well as the entire hotel load. The total installed power is 10,290 KW and total propulsion power is 8400 KW (CP propeller). To pass all the environmental legislation of IMO, 4 scrubber units is installed with the engine and generator sets. The arrangement is shown below:

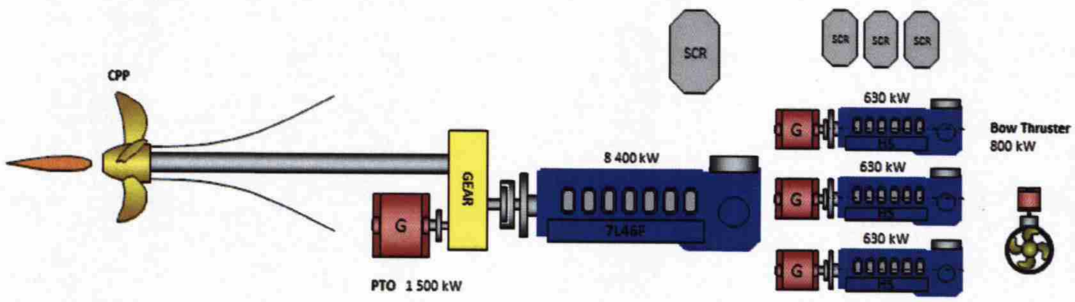


Figure 54 *Singe-screw with diesel engine machinery arrangement for the multipurpose vessel*

Total Installed Power and propulsion power

Total installed power and total propulsion power is shown in a chart for better view in the **Figure 55.**

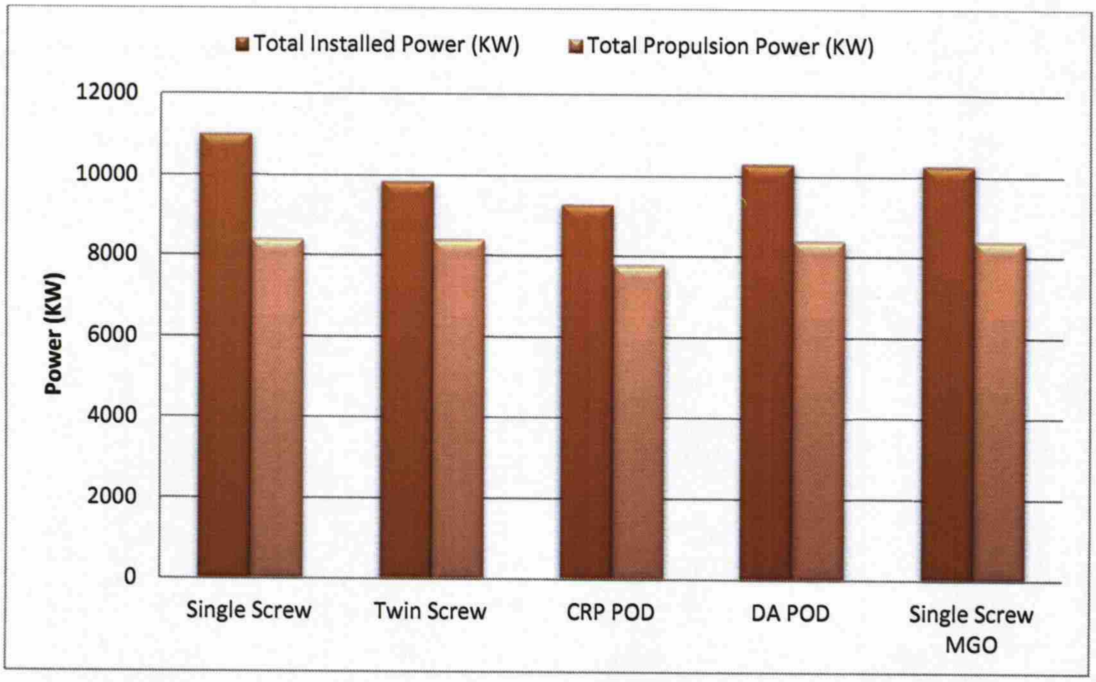


Figure 55 *Total Installed power (KW) and total propulsion power for each machinery concepts*

6.3 Results from ShipMac

Having the operational profile of the reference vessel along with power demand of all the different machinery concepts, different stages of calculation is done using the program ShipMac. The results from those calculations are described as below:

Fuel Price and consumption

Fuel price for both MGO and LNG was taken as below:

Table 6 *Fuel Price scenario Source: www.bunkerworld.com (April 2013), LNG price estimated (Big scale LNG in Europe ≈ 10 USD/MBtu, 5USD/MBtu added for distribution)*

	USD/ton	EUR/ton	USD/MBtu
MGO	1 000	765	24.7
LNG	700	534	15.0

LNG consumption by all the four cases running on dual fuel engine is shown in **Table 7**. It can be seen that the lowest amount of annual LNG consumption can be achieved with CRP POD and Single Screw machinery concepts. Bunkering duration is set for 14 days. Based on the LNG consumption, MGO consumption and fuel cost, the results from four cases are compared with the reference case running on MGO only (**Figure 56**).

Table 7 *LNG consumption by different cases*

	Single Screw	**Twin Screw**	**CRP Pod**	**Double Acting Pod**	unit
Annual LNG consumption	12 918	13 549	12 892	14 606	m^3
Daily LNG consumption	35	37	35	40	m^3
+ Margin 15%	5,3	5,6	5,3	6,0	m^3
Daily cons with margin	41	43	41	46	m^3
Volume for 14 days	570	598	569	644	m^3

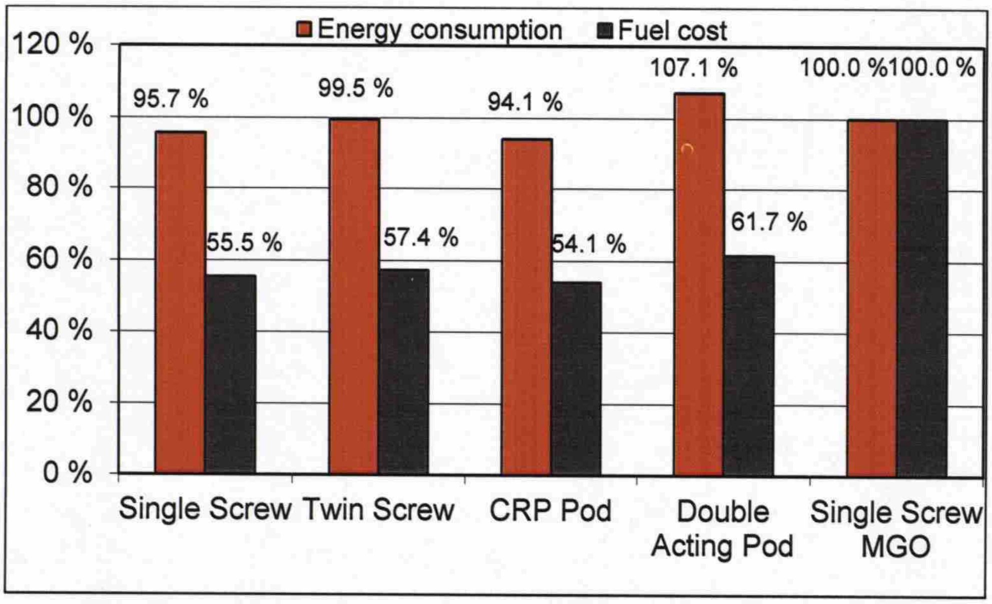


Figure 56 *Relative energy consumption and fuel cost*

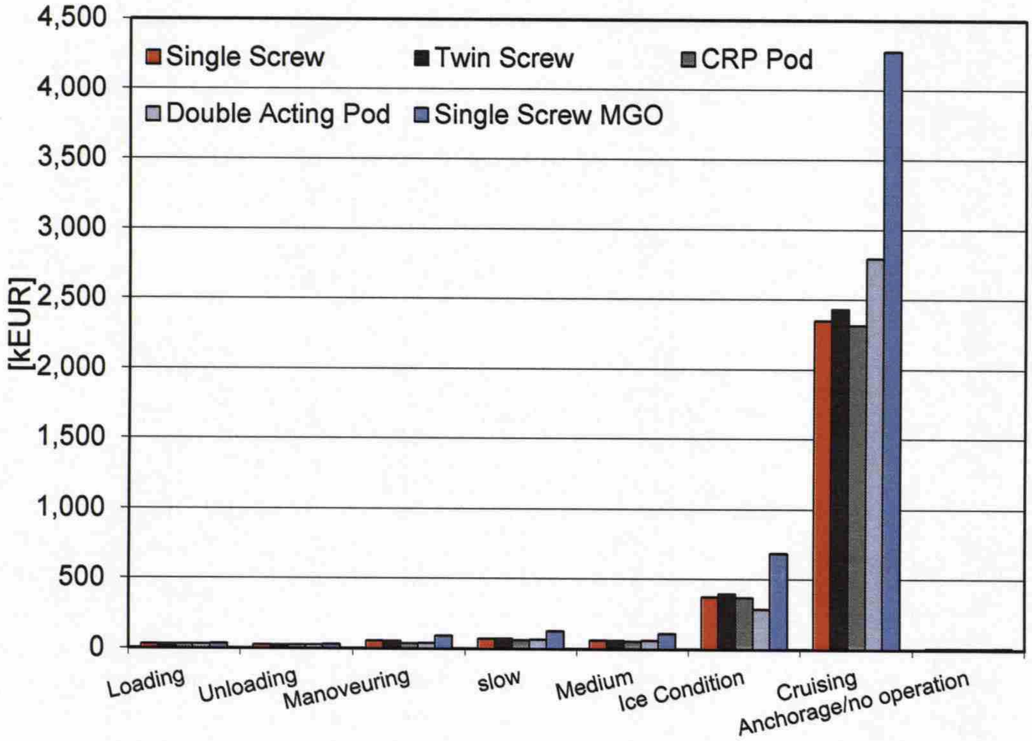


Figure 57 *Annual operation cost at different operational modes [kEUR]*

Because of fuel price difference in LNG and MGO, fuel cost for all the cases are nearly 40 to 45% lower than the reference case which is running on MGO. At the same time, energy consumption for Single-Screw and CRP-pod concepts is about 4.5% to 5.8% lower than the reference vessel. Annual operation cost (**Figure 57**) is the maximum for the Single-screw MGO concept while single-screw and CRP-POD both concept have the lowest annual operational cost with 38 kEUR difference. Annual operational cost includes the cost of Fuel, Lub oil and Urea.

Machinery Investment cost and concept payback time

The investment costs are estimated for all alternative machinery concepts and reference concept. The machinery costs are usually about 20% of the total ship price. Selection of the machinery thus effects on the total building cost of the vessel.

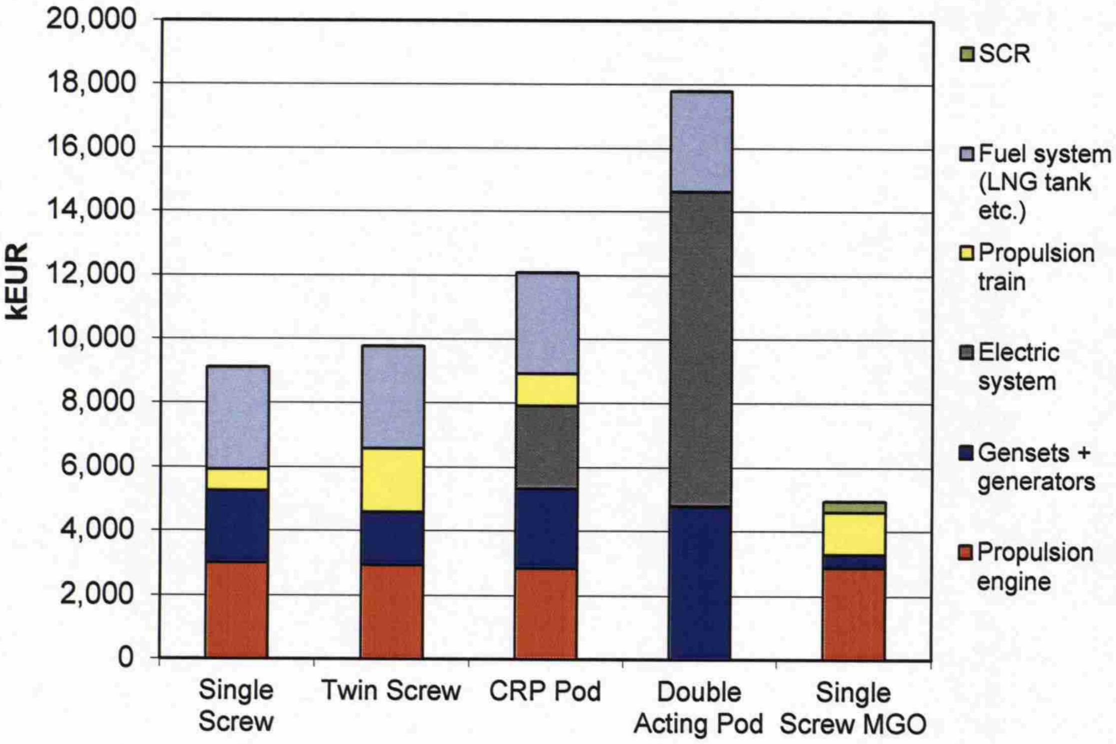


Figure 58 *Machinery First costs [kEUR]*

Lowest machinery first cost can be seen for the single-screw MGO with scrubber unit concept and the second best is single-screw dual fuel engine concept (**Figure 58**). Double acting Pod concepts are the most expensive mainly because of its expensive electric system with switchboard equipment. Fuel system includes the price of 2x 300 m^3 LNGPAC. However, even though the machinery first cost is lowest for the single-screw MGO concept, annual machinery cost is highest for it because of higher fuel price of MGO. All the machinery equipment except pods, switchboard, electrical systems price are taken from Wärtsilä and pod propulsion equipment price is from ABB. Below **Figure 59** shows the annual machinery related cost based on the assumption of 10 years repayment period with 6% interest rate. Single-screw dual fuel machinery concepts will require lowest annual machinery related cost which can save over 1.9 million EURO per year compare to single-screw MGO concept.

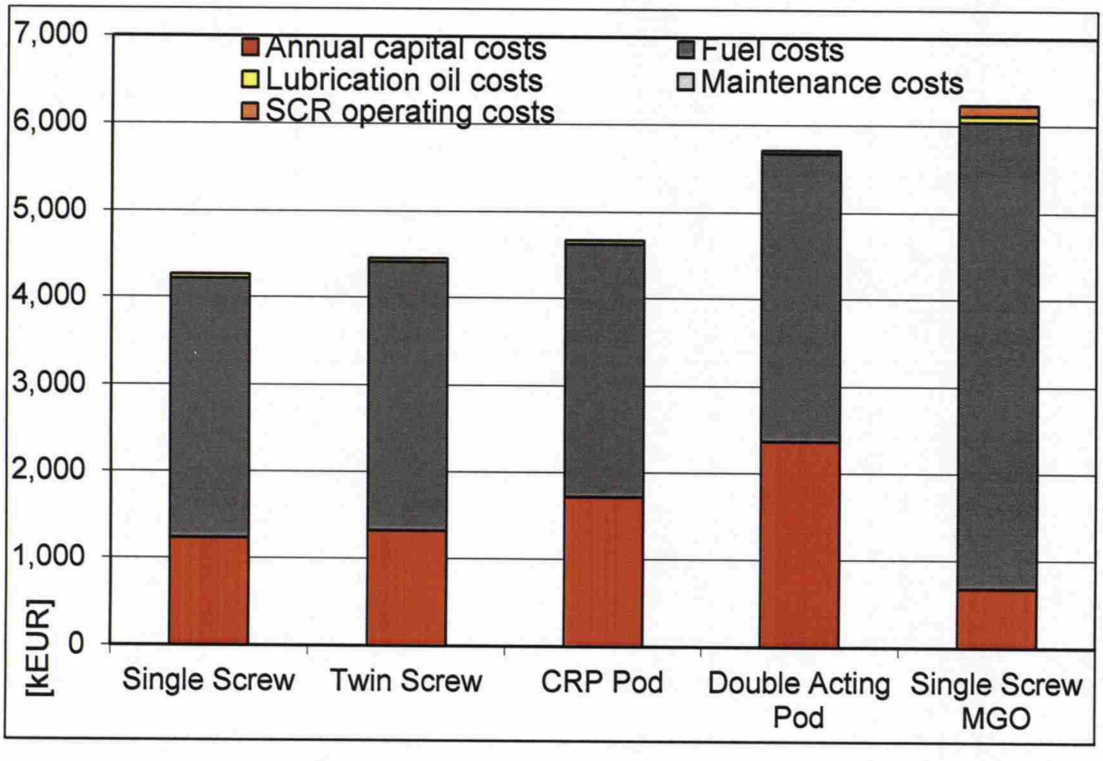


***Figure 59** Annual machinery related cost [kEUR]*

Machinery investment cost and annual operating cost are used to calculate concept payback time with respect to the reference case which is shown in **Figure 60**. Single-screw dual fuel concept has the shortest payback time of less than 2 years. Therefore, shipowners will be able to repay the investment cost for this concept in a very short time compare to other machinery concepts. All the four cases have positive number of years indicating that the reference case will require more payback time than any other concepts.

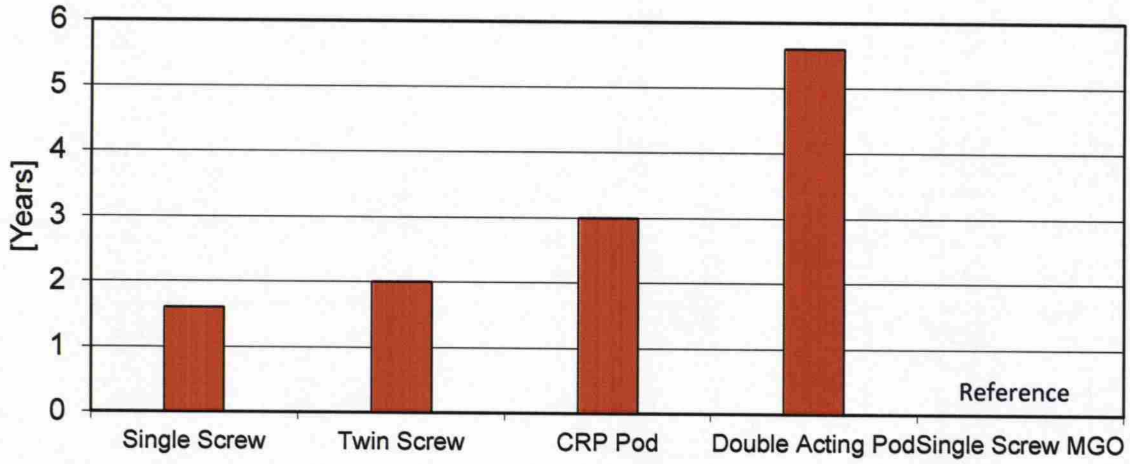


Figure 60 *concept payback time (years) for different cases*

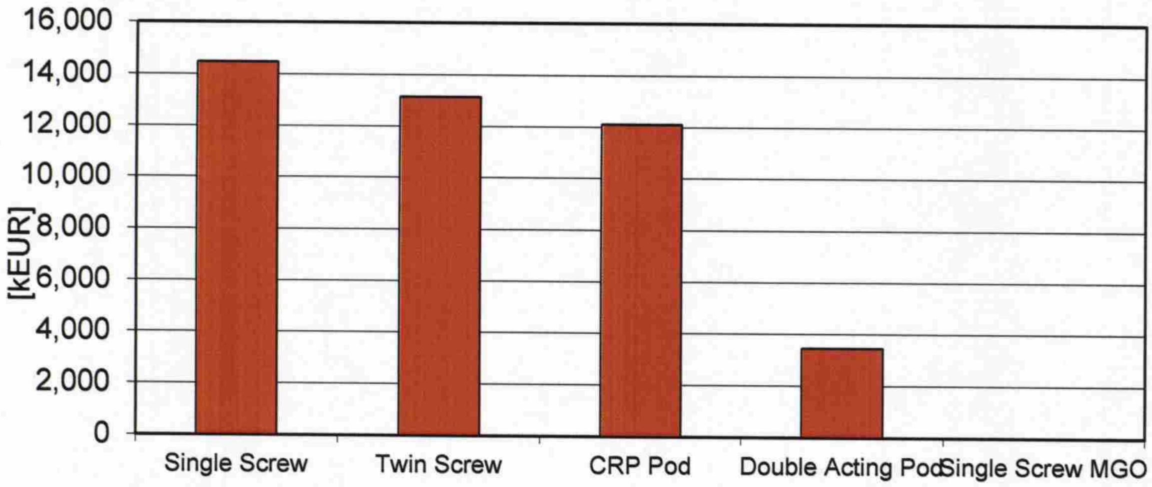


Figure 61 *Net Present Value of the machinery concepts*

Figure 61 shows Net Present Value (NPV) for the four machinery concepts with respect to the reference case. Calculation period of 10 years with 6% interest rate are assumed to calculate the NPV. Theoretically, NPV compares the value of a product at present time compare to the value of that same product in future and usually higher NPV indicates to be better. Here, single screw dual fuel concepts have the highest NPV value indicating the most profitable concept for the future.

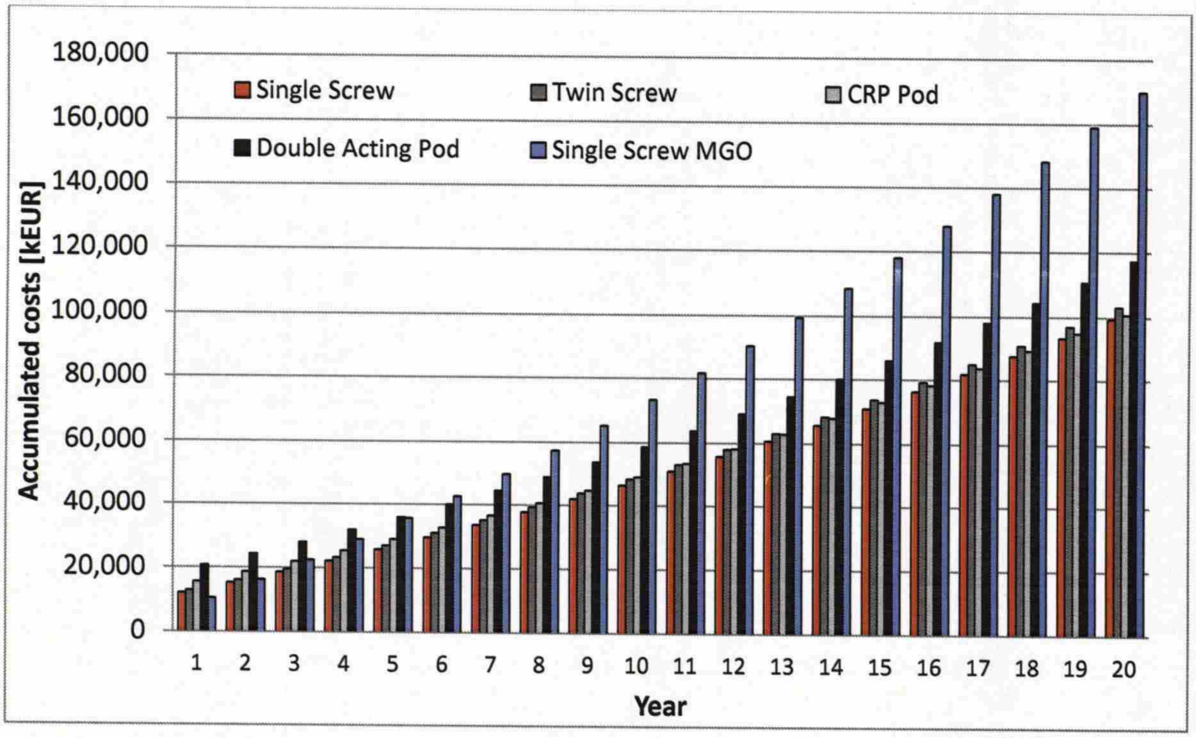


Figure 62 Accumulated costs [kEUR] for next 20 years, assuming fuel price doubled linearly.

Figure 62 shows accumulated costs for each concept for next 20 years taking the assumption of linearly doubled for fuel price. Single-screw dual fuel concept is the most economical solution for the long run. However, the cost difference between single screw dual fuel and CRP pod become less in 20th year as because of longer concept payback period for CRP pod.

Exhaust Emission

Exhaust emission of all the machinery concepts fulfills IMO Tier III NO_X regulation. Value for NO_X emission from 2-Stroke Dual fuel concepts was not available at the moment of the thesis work. However, Wärtsilä confirmed the value of NO_X emission is below 3.4 g/Kwh which also passes the Tier III requirements. To minimize the emission of Sulphur content, scrubber was installed for single-screw MGO concepts which eventually increases the investment cost as well. Benefit of LNG fuel is that it has the lowest emission of all three local pollutants NO_X, SO_X, and particles, as well as the global greenhouse gas CO_2: NO_X emissions are reduced by 85–90%, SO_X and particles by close to 100%, and net GHG emissions by 15–20% [2]. **Figure 63** below shows the percentage of change in emission with reference of Single Screw MGO concept.

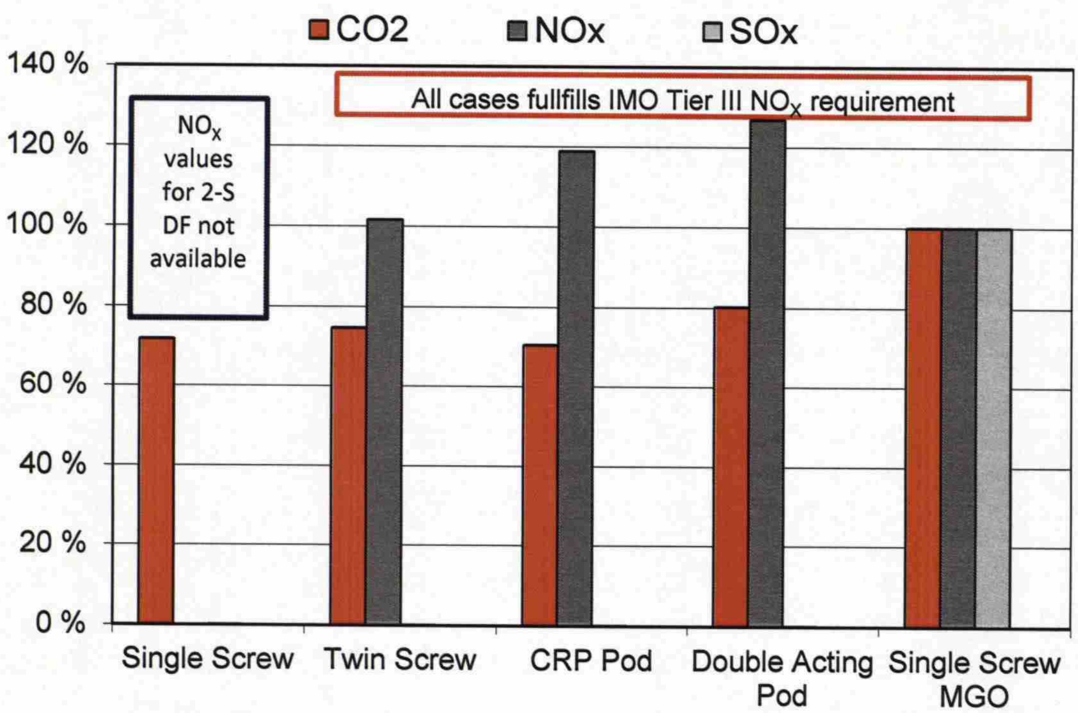


***Figure 63** Exhaust Emission of all the concepts*

6.4 Best machinery concept

For final commenting on the future best economical and environment friendly machinery concept, decision matrix is used. In each of the segments, the best concept gets the highest point of 5 and gradually down to 1 as shown in **Table 8**. Evaluating all the results discussed earlier, single screw 2-stroke dual fuel machinery concept obtains the highest point making the best suitable choice of machinery concept for the newbuildings multipurpose vessel. Even though twin-screw and CRP Pod have the same points these might change if the model testing of the vessel is done with these machinery arrangement to get more realistic values. However, it is ensured that all these alternative machinery concepts pass all the IMO pollution control regulation that will come into force in future.

Table 8 *Decision matrix for all the machinery concepts*

Cases	**LNG Cons.**	**Annual Fuel Cost & Energy Consumption**	**Machinery Investment Cost**	**Annual Machinery Cost (incl fuel cost)**	**Concept Payback Time**	**NPV**	**Total Points**
Single Screw	4	4	4	5	5	5	**27**
Twin Screw	3	3	3	4	4	4	21
CRP POD	5	5	2	3	3	3	21
DA	2	2	1	2	2	2	11
MGO+SCR	1	1	5	1	1	1	10

7 Example of MPV concept

This chapter will present some example of the concept vessel based on all the discussion and findings of previous chapters. The aim of this chapter is to give an impression of the future multipurpose vessel on the Northern Baltic Sea. It has been already discussed that the dry cargo flow on the Baltic Sea in the future is not homogenous and can be changed throughout the ship's operational lifetime. Therefore, container oriented Multipurpose vessel is suitable to meet the future shipping business need both from customers and shipowners point of view.

Based on the principal dimension of M/S Aila, several visual concepts for future multipurpose vessel were done. There were discussion on the future MPV capacity (deadweight) with Outokumpu and Langh Ship during thesis meeting, which can be regarded as customer and owners point of view. Both party agreed that the future MPV size on Baltic Sea will be about 15,000 DWT which could lead the vessel length from140 to 150 meter. As the vessel will operate both in open water and ice condition, it will have Ice class 1A super providing more flexibility during its operational lifetime. Speed of the vessel will be the same as M/S Aila which is 17.7 knots but it will be further optimized based on operational efficiency with LNG machinery concept. This vessel will have single-screw propulsion with Wärtsilä 7RT-flex50DF 2-stroke dual fuel engine solution which is proven to be best alternative machinery concept as discussed in the previous chapter.

Multiple cargo carrying scenarios has been made as show in the pictures below. The task is done using Rhinoceros and rendered using V-ray rendering plugins. Vessel size is kept similar to the multipurpose vessel M/S Aila.

Figure 64 *Multipurpose Vessel concepts*

The vessel will have 12 panel of multi folding cargotec hatch covers that can be shifted to aft and forward side (6 panel at aft position, 6 panel at forward position) to have fully open cargo hold. Two GL type crane at port side is placed for cargo handling. As the vessel should be able to carry more than 1000 TEU, container lashing system, cell guide will be available in this vessel. Crane position at side rather than the center position provides more flexibility to carry project cargos. **Figure 65** shows the vessel in open hatch condition. Volume of the cargo hold was approximately estimated to be about 14000 m^3.

Figure 65 MPV with 12 Hatch cover panel, 6 on each side.

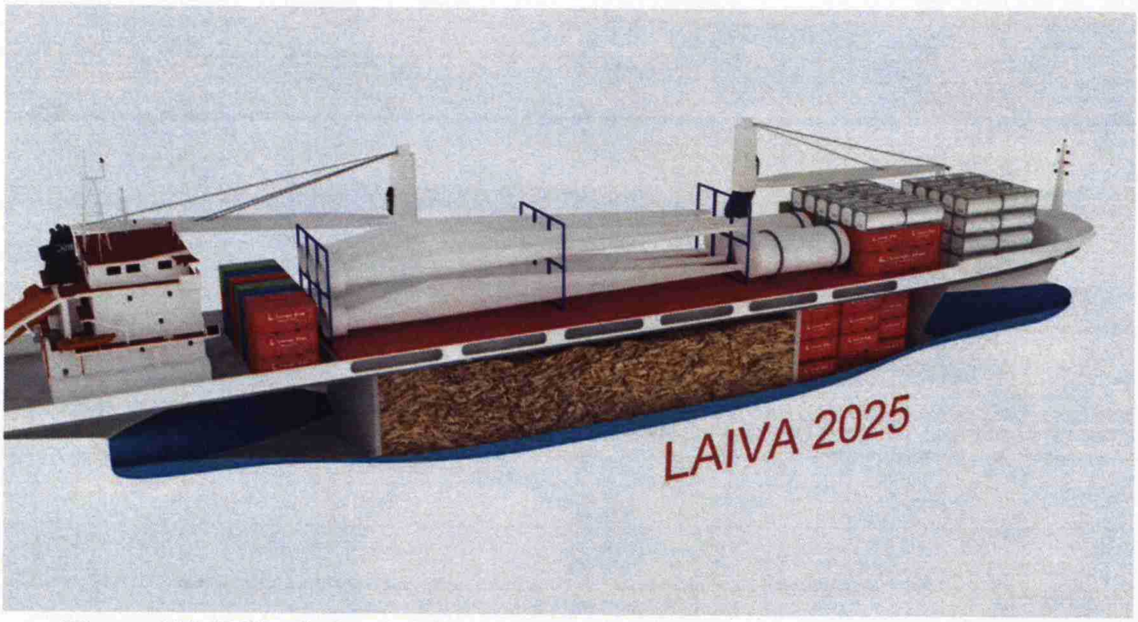


Figure 66 *MPV loaded with different cargo types (cargo hold: Wood chips, containers)*

Figure 66 shows the unique characteristics of the multipurpose vessel. Project cargo like the blades of wind turbine, different size of container can be carried securely above the hatch cover. Here, the cargo hold is carrying wood chips of about 5,600 Tonne, assuming stowage factor to be 0.4.

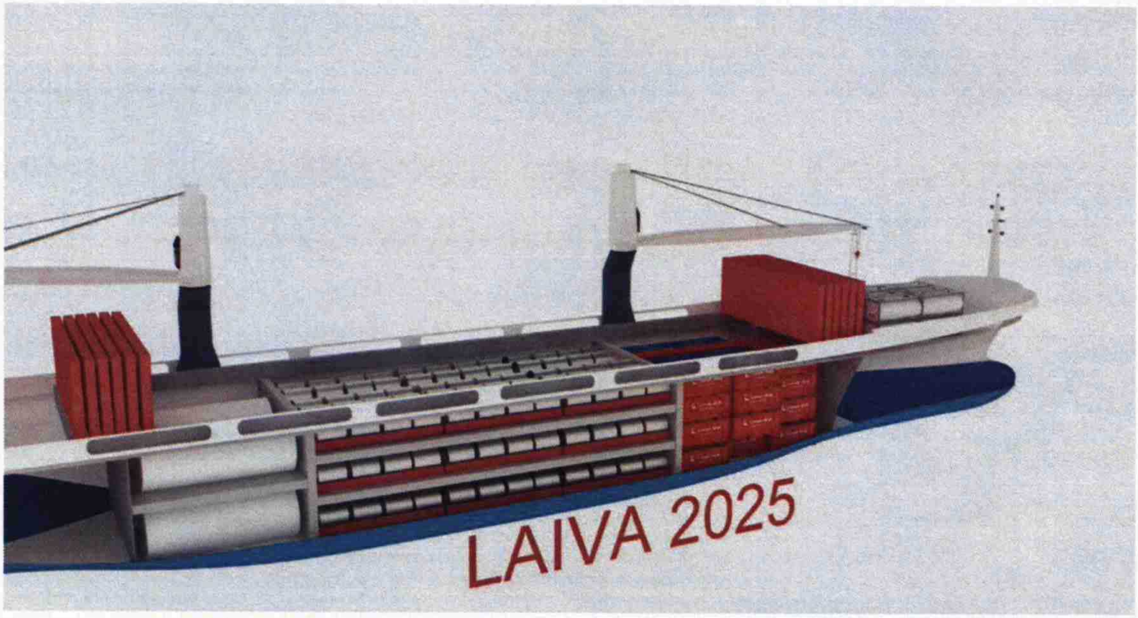


***Figure 67** MPV Loaded with Stainless steel coils on cradle in cargo hold*

Steel Coil is one of the important export products of Finland. “Cradle Cassette” is an innovative solution from the Finnish company Langh ship Oy for carrying Steel coils in the cargo hold more securely which can be fitted efficiently in the vessel.

Figure 67 shows steel coils carrying on cradle in cargo hold. Cradle Tween Deck (CTD) can also be placed as tween Deck to provide more space for carrying the steel coils safely. The CTD is based on a cradle structure that provides safe stowage for the coils without lashings and can be placed high in the cargo hold. The CTD pontoons can be lifted with the same equipment as the steel coils and, when not in use, can be piled in front of the deckhouse to free the cargo holds for other uses [52]. Flexibility of placing the ‘tweendeck with respect to the cargo hold, provides the opportunity to increase the capacity utilization of the multipurpose vessel compare to any other vessel.

Figure 68 *MPV's cargo hold loaded with paper coil, tractor, and containers*

Figure 68 shows another combination of cargo carrying capability of multipurpose vessel. Here, the paper coils are placed in the cargo hold with containers and tractors. All the above pictures provide an impression of future cargo type and transport arrangements. More detail technical research and development is required to develop an efficient standard multipurpose vessel suitable for the Northern Baltic Sea.

8 Conclusions

The study of major Finnish industry segments indicates that a non-homogenous material flow will happen in the future, therefore, demands a vessel of versatile in nature throughout the operational lifetime and at the same time fulfills all the upcoming environmental legislation. This study summarizes that container oriented multipurpose vessel will be the best solution for future dry cargo transportation on the Northern Baltic Sea. But a new trend has been seen in transporting raw materials and foodstuff which is shifting of transportation mode from bulk cargo or specialized vessel to container ship. Increasing containerization and growing container traffic causing the decrease in multipurpose vessel's market share. Multipurpose vessel's market will look turmoil for next few years because of the fierce competition with containership and handysize dry cargo vessel. Therefore, multipurpose vessel with 1000+ container capacity will be suitable for the future competition. At the same time, increasing production in the mining industry and the outlook for the export of bio-fuels as well as renewable energy sector growth in the future also provides newer opportunities for MPV. Decreasing market share for MPV is another threatening factor for this market segment although long term prospects of this segment found to be good as large amount of cargo flow will happen from metal and mining industry along with renewable power energy sector. Both shipowners and customers should combine the flow of these different cargos types to gain the maximum capacity utilization of the vessels, and therefore, collaboration with ports, logistic operators, suppliers and customers should be increased more to create the efficient logistic solution for the industry as a whole.

New IMO regulations will cause market volatility as older vessels have to install exhaust emission control system which is not only expensive solution for the shipowners but also it will eventually affect price increment in freight market. Older Ships will be either sold out of Emission Control Area (ECA) or scrapped thus creating opportunity for new vessel to enter the market. However, new vessel will have to comply with all the upcoming ECA requirements which can be fulfilled by using LNG as main fuel and advanced machinery concept as LNG has the best environmental impact and cost-effective solution. Considering the prospects of LNG as future fuel, alternative machinery concept study found that the future multipurpose vessel with single-screw 2-stroke Dual Fuel Wärtsilä engine solution will be the best solution for the vessel operating in the Northern Baltic Sea route. It has proven to be the best machinery concept compare to twin screw, CRP pod, double acting pod and single screw with MGO-scrubber solution for the multipurpose vessel in Baltic Sea condition. Standard series of multipurpose vessel and LNG fuel infrastructure development is required to create sustainable shipping industry for future. Therefore, further research recommendation will be to develop an optimum hull design along with model testing of the vessel to build an efficient standard series of multipurpose vessel which will be the most fuel efficient and profitable vessel of Future dry cargo transportation on the Northern Baltic Sea.

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Appendix

Power demand curve for the alternative machinery concepts

Open Water condition

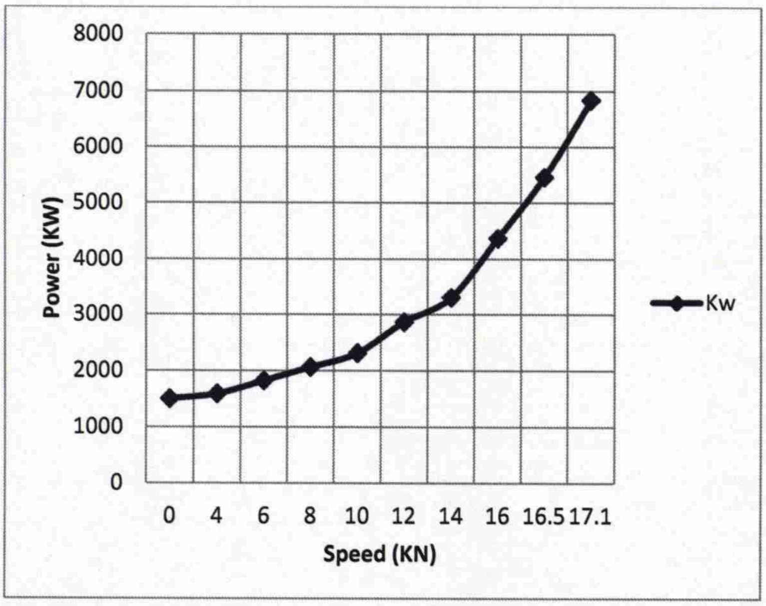

Figure 69 *Propulsion power demand for CRP POD concept at different speed*

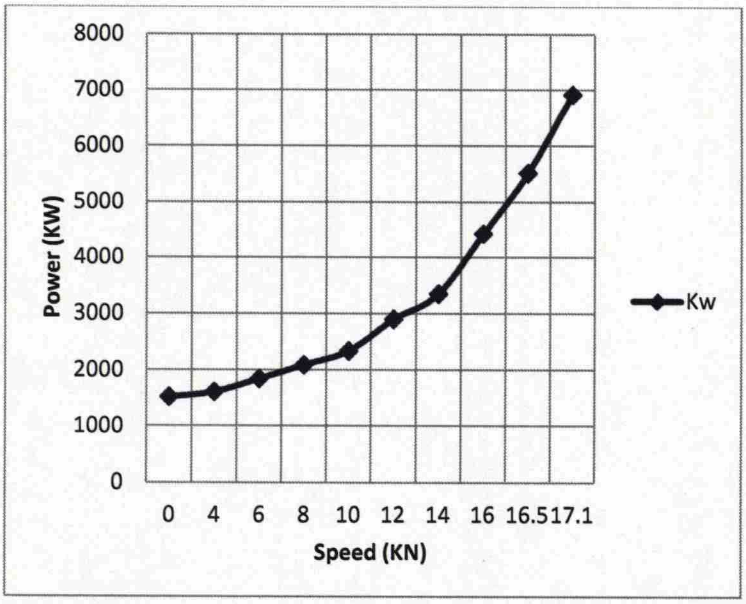

Figure 70 *Propulsion power demand for Twin-screw concept at different speed*

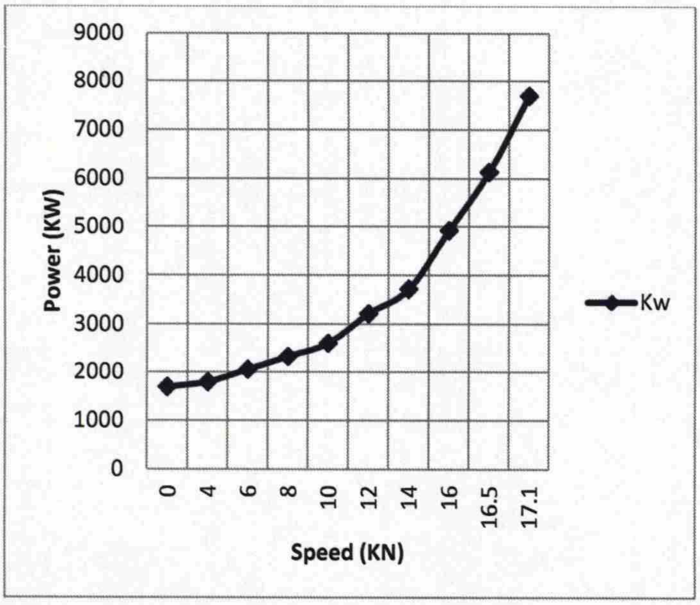

Figure 71 *Propulsion power demand for Double Acting concept at different speed*